Final Report

A project under the Canada
New Brunswick Conservation
and Renewable Energy
Demonstration Program

Telephone (506) 456-3391
Telex 014-47446
Cable "Connors"

CONNORS BROS., LIMITED Black's Harbour, New Brunswick, E0G 1H0, Canada

CONNORS SEAFOODS
BRUNSWICK SARDINES
Nutrition...naturally!

NB 45

FISH OIL AS AN ALTERNATIVE FUEL

CONNORS BROTHERS LTD.

Blacks Harbour, N.B.

December, 1984

C.R.E.D.A. Project 2040

Project Managers:

W.N. Walsh, P.Eng.
General Manager - Engineering

F. Stevens
Energy Conservation Co-ordinator

Canada/New Brunswick Conservation and Renewable Energy Demonstration Program

The Conservation and Renewable Energy Demonstration Program Program is administered in New Brunswick by the Energy Secretariat and managed jointly with Energy, Mines and Resources Canada. The Program is designed to help demonstrate promising conservation and renewable energy technologies, to develop public awareness and understanding of these technologies, and to create employment in new or existing industries.

Through over 100 demonstration projects in New Brunswick, a wide variety of conservation and renewable energy technologies have proven to be technically sound and economically attractive. These demonstration projects should now provide a catalyst for commercialization and lead to widespread adoption of many of these proven technologies.

This final report is based on a project which was financially supported by the Energy Demonstration Program. For further information on other demonstration projects funded in New Brunswick under this program, contact:

Conservation & Renewable
Energy Division
Energy Secretariat
P.O. Box 6000
Fredericton, N.B.
E3B 5H1
(506) 453-3897

Programme Canada/Nouveau-Brunswick de démonstration des économies d'énergie et des énergies renouvelables

Le Programme de démonstration des économies d'énergie et des énergies renouvelables est administré au Nouveau-Brunswick par le Secrétariat à l'énergie, en collaboration avec Energie, Mines et Ressources Canada. Ce programme tente d'abord de vérifier la fiabilité des techniques de conservation d'énergie, d'accroître la sensibilité du public envers ces techniques et, enfin, de favoriser la création d'emplois au sein des industries nouvelles ou déjà existantes.

Un grand nombre de projets de démonstration se sont avérés à la fois techniquement réalisables et économiquement attrayants.

Le succès ainsi rencontré encourage la commercialisation des procédés les plus accessibles. Cela entraînerait certes l'adoption d'un grand nombre de ces techniques par les propriétaires de domiciles et par l'industrie privée.

Ce rapport final est basé sur un projet qui a reçu une aide financière du Programme de démonstration. Pour de plus amples renseignements, communiquez avec la:

Division des économies d'énergie
et des énergies renouvelables
Secrétariat à l'énergie
C.P. 6000
Fredericton, N.-B.
E3B 5H1
(506) 453-3897

D I S C L A I M E R

This report, funded by the New Brunswick Energy Secretariat and Energy, Mines and Resources Canada, is published as a public service for the information of the public. The parties do not, however, warrant the accuracy of its contents and cannot guarantee or assume any liability for the effectiveness of economic benefits of the devices and processes described in the report or that their use does not infringe privately-owned rights.

D E N I D E R E S P O N S A B I L I T E

Ce rapport, financé conjointment par le Secrétariat à l'énergie du Nouveau-Brunswick et Energie, Mines et Ressources Canada, est publié à titre de service public. Les gouvernements fédéral et provinciaux n'assurent aucunement l'exactitude du contenu, l'efficacité des appareils et des procédés et, enfin, les économies que préconise le rapport. L'utilisation de ces systèmes de conservation d'énergie ne doit, à aucun moment, empiéter sur les droits d'autrui.

TABLE OF CONTENTS

		PAGE
	EXECUTIVE SUMMARY	1
1.	INTRODUCTION	3
2.	TECHNICAL BACKGROUND	5
3.	EXPERIMENTS CONDUCTED	10
4.	RESULTS OF EXPERIMENTS	13
5.	CAPITAL COSTS	17
6.	ECONOMICS	18
7.	INFORMATION TRANSFER	22
8.	CONCLUSIONS	23
9.	RECOMMENDATIONS	26

APPENDICIES

1. Technical Background - Details
2. Capital Cost - Details
3. Consultant's Report
   - Appendix A: Summation of Data; Oil consumed versus steam produced
   - Appendix B: Boiler Specifications
   - Appendix C: A.S.M.E. Abbreviated Efficiency Tests
   - Appendix D: Specificaton of Instruments Used

EXECUTIVE SUMMARY

The object of this demonstration project was to investigate the feasibility of using fish oil as an alternative fuel. Can fish oil be burned practically without significant side effects and what are the economics? What technology is required to burn fish oil as a fuel in industrial boilers? In February '82 an application was forwarded to the N.B. Energy Secretariat's office requesting financial assistance under their Conservation and Renewable Energy Demonstration program (CREDA). The assistance was required to demonstrate the feasibility of using fish oil as an alternate fuel, so that the technology could be extended to other fish plants in Canada. The application was accepted and the project was completed between May 21, 1982 and April 1, 1983.

Connors Bros., Limited is the largest sardine producer in North America, producing over 1,000,000 cases of canned sardines, 100 cans/case, per year. The fish waste from our sardine plants is processed as fishmeal. A by-product of our fishmeal operation is fish oil. Connors Bros. produces from 400-500,000 gallons of fish oil annually. The market value of fish oil has dropped in the past 4 years, whereas residual fuel oils have increased over 250%. Fish oil is currently used in margarines, paints and tannery operations. Fish oil as a fuel, if feasible, could replace 90% of the residual fuels used in Connors two largest operations at Blacks Harbour, N.B. The fish oil used in this case is herring oil.

Bunker C fuel oil is widely accepted and used in industrial operations today, due mainly to its low cost and high energy content.

After analyzing the results of Lab tests on fish oil, the physical and chemical properties show it to be a viable fuel oil. When comparing it to residual fuel oils we find fish oil to have a pour point, flash point and viscosity level similar to a #4 oil. The major deficiency of fish oil is a loss of heat content of 14.54% when compared with #6 Bunker C oil on a volume basis.

Fish oil was burned in two fishmeal driers, a Cleaverbrooks boiler (200 h.p) and a Volcano watertube boiler (35,000 lbs/hour). The Volcano was monitored for a month while 23,000 gals of fish oil were burned under production conditions and the results compared with Bunker C #6.

Several fishing companies in Newfoundland and Nova Scotia with fishmeal plants using oily fish (herring) have contacted Connors for information regarding burning fish oil and were

burning fish oil for processing and heating. They have since stopped due to the sudden increase in fish oil price.

In conclusion, it was found that fish oil is a viable technical alternative to residual fuel oils. To use fish oil as a fuel in the future is a definite alternative providing fuel prices prove it economically feasible.

SOMMAIRE

L'objet de ce projet de démonstration était d'évaluer la faisabilité de l'utilisation de l'huile de poisson comme combustible de rechange. Peut-on, en effet, brûler de l'huile de poisson de façon pratique sans effets secondaires importants et quels en sont les avantages économiques? Quelles technologies est-il nécessaire d'appliquer pour brûler de l'huile de poisson comme combustible dans les brûleurs industriels? En février 1982, une demande était soumise au Secrétariat à l'énergie du Nouveau-Brunswick pour obtenir une assistance financière en vertu du Programme de démonstration des économies d'énergie et des énergies renouvelables (ADEEER). Cette assistance devait permettre de démontrer la faisabilité de l'utilisation de l'huile poisson comme combustible de rechange afin de pouvoir transmettre cette technologie à d'autres usines de transformation du poisson au Canada. La demande a été acceptée et le projet a été réalisé entre le 21 mai 1982 et le 1er avril 1983.

Connors Bros., Limited est le plus important producteur de sardines en Amérique du Nord, produisant plus d'un million de caisses de sardines en boîte, soit 100 boîtes par caisse, par année. Les résidus de poisson de nos usines de sardines sont transformés en guano de poisson, dont l'un des dérivés est l'huile de poisson. Connors Bros. produit de 400 à 500 000 gallons d'huile de poisson par année. La valeur marchande de l'huile de poisson a baissé au cours des 4 dernières années, tandis que les huiles combustibles résiduelles ont augmenté de plus de 250%. L'huile de poisson est actuellement utilisée dans les margarines, les peintures et les établissements de tannerie. S'il était possible de la transformer en combustible, l'huile de poisson pourrait remplacer 90% des combustibles résiduels utilisés dans les deux plus importantes usines de Connors à Blacks Harbour, au N-B. L'Huile de poisson utilisée dans ce cas est l'huile de hareng.

Le mazout de catégorie C est généralement accepté et utilisé dans les entreprises industrielles d'aujourd'hui, principalement en raison de son faible coût et de sa valeur énergétique élevée.

Les résultats des analyses de l'huile de poisson en laboratoire ont démontré que ses propriétés physiques et chimiques en font un combustible viable. En la comparant aux huiles combustibles résiduelles, on peut constater que l'huile de poisson présente un point de consistance liquide, un point d'inflammation et un degré de viscosité semblables au mazout numéro 4. Le principal désavantage de l'huile de poisson est sa perte d'enthalpie de 14,54 % comparativement au mazout de catégorie C numéro 6 à volume égal.

L'huile de poisson a été utilisée dans deux séchoirs de guano de poisson, soit un Cleaverbrooks (200 c.v.) et une chaudière à tubes d'eau Volcano (35 000 lbs/heure).
On a surveillé la chaudière Volcano pendant une période d'un mois au cours de laquelle 23 000 gallons d'huile de poisson ont été

brûlés dans des conditions ordinaires de production et les résultats ont été comparés avec ceux du mazout de catégorie C numéro 6.

Plusieurs entreprises de transformation du poisson à Terre-Neuve et en Nouvelle-Ecosse dont les usines de guano de poisson fonctionnent uniquement à l'huile de poisson (hareng) nous ont contactés pour obtenir des renseignements concernant cette question et ont effectivement utilisé l'huile de poisson pour la transformation et le chauffage. Ces entreprises ont cessé cette pratique depuis étant donné l'augmentation soudaine du prix de l'huile de poisson.

En conclusion, on a constaté que l'huile de poisson est une technique de rechange viable pour remplacer les huiles combustibles résiduelles. L'utilisation future de l'huile de poisson en tant que combustible est définitivement une solution de rechange à la condition que le coût de ce combustible s'avère économiquement viable.

CHAPTER 1

INTRODUCTION

1. OBJECT

The object of this demonstration project was to investigate the feasibility of using fish oil as an fuel alternative. Can fish oil be burned practically without significant side effects and what are the economics?

2. HISTORY

a) In February '82 an application was forwarded to the N.B. Energy Secretariat's office requesting financial assistance under their Conservation and Renewable Energy Demonstration program (CREDA). The assistance was required to demonstrate the feasibility of using fish oil as an alternate fuel, so that the technology could be extended to other fish plants in Canada.

b) A letter of approval was signed by Finance Minister, Fernand Dube, on April 7, 1982.

c) Contract was signed on September 29, 1982.

d) Project completed: May 21, 1982 - April 1, 1983.

3. BACKGROUND

Connors Bros., Limited is the largest sardine producer in North America, producing over 1,000,000 cases of canned sardines, 100 cans/case, per year. The fish waste from our sardine plants is processed as fishmeal.

A by-product of our fishmeal operation is fish oil. Connors Bros. produces from 400-500,000 gals of fish oil annually. The quantity of oil produced will depend on quantities of fish landed plus the fat content of these fish.

The market value of fish oil has dropped in the past 4 years, whereas residual fuel oils have increased over 250%. Fish oil is currently used in margarines, paints and tannery operations. Fish oil as a fuel, if feasible, could replace 90% of the residual fuels used in Connors two largest operations at Blacks Harbour, N.B.

At times Connors must store up to 160,000 gals of fish oil until markets are found or shipping containers are available. This would take eight 20,000 gals storage tanks, steam lines to heat the oil and constant maintenance. The quality of this oil, which determines its market value, is a concern when storing for long periods of time. Also a concern is the increasing inventory costs.

4. TECHNOLOGY TO BE DEMONSTRATED: Questions To Be Answered

1. Does fish oil have the physical and chemical properties to make it a viable fuel oil?
2. What technology is required to burn fish oil as a fuel in industrial boilers?
   a) Type of equipment needed.
   b) Proper procedure for most efficient combustion.
   c) Proper procedure in storing fish oil.
3. At what point would it be economically feasible to burn fish oil as a fuel?
4. Environmental advantages or disadvantages.
5. Possible long-term advantages or disadvantages on boiler maintenance when using fish oil as a fuel.

NOTE: The fish oil used in this case is herring oil.

CHAPTER 2

TECHNICAL BACKGROUND

1. FISHMEAL PLANT - SOURCE OF FISH OIL

Fishmeal plants are an integral part of the fish processing industry. The waste fish (offal) from fish processing plants is transported to fishmeal plants where it is processed into fishmeal, fish oil and fish solubles which are sold in worldwide markets.

Appendix 1-1 presents a detailed description of the #3 Fishmeal Plant process and describes how fish oil is produced. Figure 2-1 presents a plan view of #3 Fishmeal Plant showing the fish oil storage tanks and the boilers in which the experimental burns were conducted.

2. BUNKER C COMBUSTION THEORY (See Table 2-1 For Specs)

The most common fuel used today in large industrial boilers is #6 Bunker C. Although the technology required to burn this oil is much more complex than more refined oil, the economic advantages outweigh the disadvantages of higher technology. Bunker C is widely accepted and used in industrial operations today, due mainly to its low cost and high Btu content. Bunker C is a black viscous fuel oil which requires rather expensive preheating equipment in order to burn properly. The chemical composition of Bunker C #6 oil is high in sulfur, sodium and vanadium, which play a major part in contributing to sludging and corrosion problems in industrial boilers. For more detail see Appendix 1-2.

3. PHYSICAL & CHEMICAL PROPERTIES OF FISH OIL

1. Lab Analysis:

   Results are summarized and listed with residual fuels for comparison purposes in Table 2-1.

2. Viable Fuel Oil:

   After analyzing the results of Lab tests on fish oil, the physical and chemical properties show it to be a viable fuel oil.

3. Different From #6 Bunker C:

   The physical and chemical properties of fish oil are substantially different from #6 Bunker C.

4. Stable:

The physical properties and chemical composition show fish oil to be relatively stable.

5. Impurities:

The fish oil tested was an unrefined oil and had only .105% sulfur, 1.22% sodium (salt), 0% vanadium and very low ash content. There is a small amount of water and salt (sodium chloride) in the fish oil. This occurs as a result of the handling process of the fish.

6. Similar To A #4 Oil:

From a visual inspection of fish oil it can be seen that it is liquid at room temperature, it is dark in colour and has a characteristic odour of fish. In visual appearance, it is quite similar to #4 fuel oil. When comparing it to residual fuel oils we find fish oil to have a pour point, flash point and viscosity level similar to a #4 oil (see Table 2-1). It can be seen in Table 2-1 that with the exception of the heating value, the fish oil and the #4 oil are quite similar. The reason for the lower heating value is the low carbon content of the fish oil. Fish oil contains only 77.54% carbon while a fuel oil contains approximately 10% more carbon. As carbon contains 14,500 Btu/ Lb, 10% more carbon would increase the heating value of the fish oil to:

$$16,632 + 1,450 = 18,082 \text{ Btu/Lb.}$$

which would put it in the range of a fuel oil.

4. HEAT CONTENT OF FISH OIL VS #6 BUNKER C

a) By Weight:

Normal heat content of a #6 oil is 18,300 Btu/Lb (see Table 2-1). This means that the heat content of the fish oil is reduced by:

$$\frac{18,300 - 16,632}{18,300} \times 100 = 9.1\%$$

Therefore, there is a reduction in the heat content of the fuel by 9.1% on a weight basis.

b) By Volume:

Normally, the density of #6 oil will vary 9.22 lbs/gal. to 10.22 lbs/gal. with the average being 9.72 lbs/gal. If we consider the difference in density, then the loss of heat content of the fish oil becomes much greater:

$$\frac{18{,}300 \times 9.72 - 16{,}632 \times 9.14}{18{,}300 \times 9.72} \times 100 = 14.54\%$$

Therefore, there is a loss of heat content in the fish oil of 14.54% when compared with #6 Bunker C oil on a volume basis.

Figure 2.1

Connors Brothers Limited
Blacks Harbour, N.B.

No. 3 Fishmeal Plant

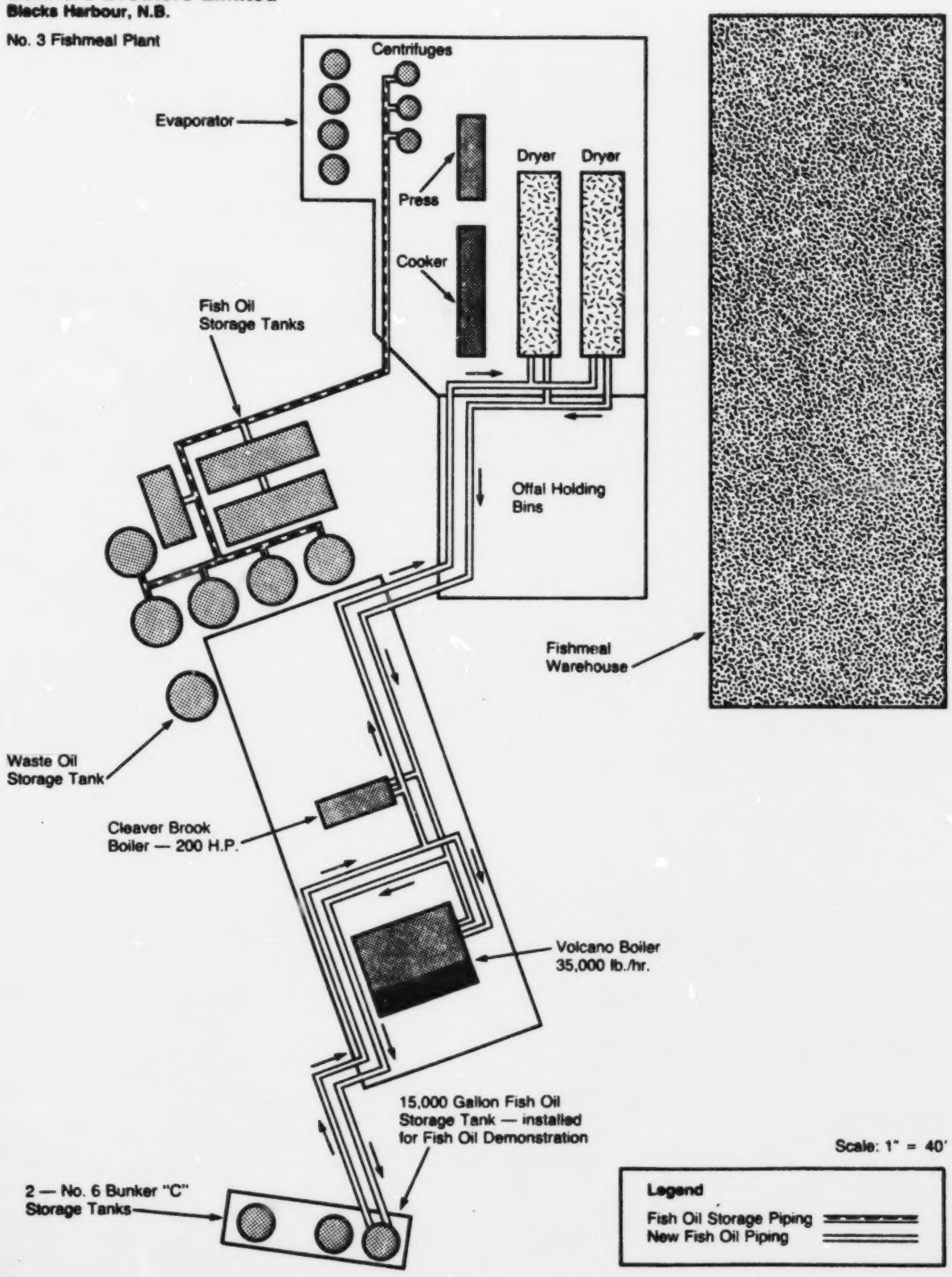


TABLE 2-1

SPECS RESIDUAL FUEL OILS PLUS FISH OIL

GRADE OF FUEL OIL	NO. 1	NO. 2	NO. 4	NO. 5	NO. 6	FISH OIL***
WEIGHT, PERCENT:						
Sulfur	0.1	0.3	0.8	1.0	2.3	0.105
Hydrogen	13.8	12.5	-	-	9.7	11.76
Carbon	86.1	87.2	-	-	85.6	77.54
Nitrogen	-	0.02	-	-	2.0	-
Oxygen	Nil	Nil	-	-		-
Ash	Nil	Nil	0.03	0.03	0.12	0.005
Salt	Nil	Nil	Nil	Nil	Nil	1.22
GRAVITY:						
Deg API	42	32	20	19	17	23.3
Specific	0.815	0.865	0.934	0.94	0.972	0.914
Lb. Per Gal. (Imp.)	8.15	8.65	9.34	9.4	9.72	9.14
POUR POINT, F	-35	-5	+20	+30	75	+31
FLASH POINT, F						219
VISCOSITY:						
Centistokes @ 100 F	1.8	2.4	27.5	130	750	36.1
SUS @ 100 F	-	34	130	-	-	-
SSF @ 122 F	-	-	-	30	45-300	-
WATER & SEDIMENT, VOLUME %	Nil	Nil	0.2	0.3	0.74	.5 to 2
HEATING VALUE:						
Btu/Lb, Gross	19,810	19,430	18,860	18,760	18,300**	16,632
Btu/Gal, Gross	161,451	162,000*	176,152	176,344	177,876	152,016

NOTES: * Actual Btu content of #2 oil from Irving Oil is 162,000 Btu/Gal.. This value (162,000 Btu/Gal.) is used in comparisons throughout the report. Based on density, value = 168,069 Btu/Gal.

** Bomb calorimeter determination.

*** This is an unrefined herring oil.

Four different lab tests were done to determine the physical and chemical properties of fish oil for use as a fuel oil. Three tests were done by Atlantic Analytical Services Limited of Saint John, N. B.. Another test was done by Canadian Combustion Research Lab (EMR) in Ottawa by Dr. Win Lee of Canmet.

CHAPTER 3

EXPERIMENTS CONDUCTED

1. INTRODUCTION

This chapter will present the detail of the experiments conducted between Sept. 7 and Oct. 14/82 in burning fish oil. A consultant, Jim Hall of Carvern Petrochemical Co., Limited (CV100), who is a combustion efficiency technologist with proper test equipment, was hired to aid in the experiments and to summarize the findings in a report. Appendix 3 presents his report, which includes a detailed account of this chapter. After analyzing the Lab reports it was agreed that fish oil with its physical and chemical properties should burn very well and would probably burn unblended, which is what was tried.

2. FISHMEAL DRIER BURNERS

Connors has two direct flame dryers in our Fishmeal operation. These dryers are equipped with different burners:

a) No. 1 Dryer has a steam atomizing natural draft burner.
b) No. 2 Dryer has a rotary cup natural draft burner.

The fish oil was fed to the burners at 100 F on Sept. 7/82. The first objective was to establish the proper oil temperature for most efficient combustion. Secondly, it was attempted to establish proper combustion air. Dryers could only be run for a short period of time due to lack of fish. Once fish oil temperature was raised to 100 F, ignition was smooth and immediate.

4. CLEAVERBROOKS BOILER (200 H.P.)

The next objective was to try burning fish oil in the 200 h.p. Cleaverbrooks boiler. Oil temperature was raised to 125 F and burner combustion controls were set for Bunker C #6 oil with the use of a flue gas analyzer. The boiler was tried on low, medium and high fire. Constant checks were made visually on the flame and on readings from the flue gas analyzer. Efficiency calculations were done periodically by the consultant and recorded in his report.

The boiler started quite roughly at first but once proper oil temperature and pressure were established the fish oil burned very well. At one point we were getting a few minor furnace explosions which were attributed to fish oil being too hot, and the burner cone was damaged and had to be repaired. However, fish oil at the proper temperature and pressure will burn very well in a Cleaverbrooks boiler equipped with an oil preheater and an air atomizing force draft burner.

4. VOLCANO BOILER (35,000 LBS/HOUR)

The next step was burning fish oil in the 35,000 lbs/hour Volcano water tube boiler. This boiler has a steam atomizing forced draft burner with a light oil ignition. On September 9, 1982 the Volcano boiler was started on fish oil. Using a flue gas analyzer, burner controls were set to give the most efficient combustion. This boiler was run all evening on low loads and operators made visual checks on performance of the boiler. Once oil temperature and pressure were established the fish oil burned very well. Inspections of the fire box or combustion chamber showed no signs of soot or sludge build-up and the gun tips had less carbon build-up than would have been the case with Bunker C #6. During this time visual checks were done on the flame, which seemed constant and bright.

5. FULL LOAD CONDITIONS (1 DAY)

The next step was to burn fish oil under full load conditions. This was done on September 10, 1982 when we burned approximately 1,400 gals of fish oil in 10 hours. All burners performed satisfactorily. Operator's comments were all positive.

Again, data was collected on the hour, both visually and from instrumentation readings. This data collecting consisted of checking fuel oil tank levels on the hour to compare with meter readings plus noting any unusual performance of boilers that might be attributed to the burning of fish oil.

6. FULL LOAD CONDITIONS (1 MONTH)

In all we burned approximately 23,000 gals of fish oil over a four week period, during which we had several days of non-production due to lack of fish. Accurate data was kept on over 12,000 gals (2 weeks) of fish oil burned during this period. A similar period of time (2 weeks) was recorded using Bunker C #6 fuel for comparison with results of fish oil performance.

A monitoring system was established in which boiler operators were to collect data on the hour for every hour the boiler was burning fish oil or Bunker C. Data collected on the hour was:

a) Stack Temperatures
b) Oil Pressure
c) Oil Temperature
d) Fuel Used
e) Make-up Water Used
f) Steam Atomizing Pressure

A summary of the data collected is included in Appendix A of Consultant's report (Appendix 3). This monitoring was conducted to try to ascertain:

1. Burner modifications required.
2. Proper fuel temperature.
3. Proper air to fuel ratio.
4. Required atomization.

Fireside inspections of combustion chamber were carried out when the process was halted for a few days due to the lack of fish for fishmeal.

CHAPTER 4

RESULTS OF EXPERIMENTS (FISH OIL VS BUNKER C #6)

1. BTU/GAL. COMPARISON - MEASURED

From September 10, 1982 to October 14, 1982 our Boiler Room personnel kept records of the oil consumed versus steam produced and a summation is given in Appendix A of Consultant's Report (Appendix 3).

On the 8 days the fish oil was burned and steam flow recorded, 8,772.4 gals of fish oil produced 105,927.5 lbs of steam or:

$$\frac{105,927.5}{8,772.4} = 120.75 \text{ lbs of steam/gal. of oil}$$

On the 13 days that #6 Bunker C oil was burned and steam flow recorded, 14,273.25 gals. of oil produced 2,113,313 lbs of steam or:

$$\frac{2,113,313}{14,273.25} = 148.06 \text{ lbs of steam/gal. of oil}$$

This means that there is a net loss of steam production of:

$$\frac{148.06 - 120.75}{148.06} \times 100 = 18.45\%$$

2. VOLCANO BOILER COMBUSTION EFFICIENCY MEASURED

Fish Oil = 80.02%
Bunker C #6 = 81.74%
Difference = 1.72%

NOTE: Using fish oil as a fuel it was found that it was necessary to increase excess air from 1-5% to prevent smoking. This gave a loss of approximately 2% in combustion efficiency.

3. RECONCILIATION OF BTU/GAL LOSS MEASURED VS THEORETICAL

1. Measured Btu/Gal. loss = 18.45% (see 4.1 above).
2. Theoretical Btu/Gal. Loss = (14.5%) (see Chapter 2.5).
3. Loss in Combustion Efficiency = (1.72%). See 4.2 above.

Unexplained = 2.19% - This is a reasonable error as it is within the accuracy of the

experiment.

NOTE: As there is a lower heat content of the fish oil, it will require more fish oil to produce the same amount of steam as with #6 C oil. If the oil pumping system cannot deliver enough oil, or the fan cannot deliver enough air, it may limit the maximum output of the boiler to a lower quantity of steam than with #6 C fuel oil. It may derate a unit by as much as 18%. While burning fish oil it was not apparent from the performance of the boiler that the heating value was less than #6 Bunker C.

4. CONVERSION COST FROM BUNKER C TO FISH OIL

When converting from #6, #5 or #4 fuel oil to fish oil there should be no conversion costs and only minor burner adjustments required. Only minor changes need to be made in proper air to fuel ratio, fuel temperatue and atomization.

Modifications required to burn fish oil:

a) When boiler is equipped to burn #6 oil all that is required is to:

1. Set oil preheat temperature to 120-140 F.
2. Increase excess air approximately 5%.

b) When boiler is equipped for light oil only, an oil preheater should be installed to maintain 120-140 F.

5. TYPE OF BOILER WHICH CAN BE USED

Fish oil can quite easily be used as fuel in a water tube boiler, firetube boiler or fishmeal dryer. Fish oil can be burned in most industrial boilers equipped with either natural draft steam atomizing, rotary cup, air atomizing forced draft or steam atomizing foced draft conventional burners.

6. COMBUSTION CHARACTERISTICS

a) The oil lights well and burns well.

b) Combustion characteristics are similar to a #4 fuel oil (see Table 2-1) and required combustion equipment to burn fish oil is also similar to a #4 fuel oil. The combustion equipment required to burn fish oil is minimal compared to Bunker C #6. The high viscosity and lower pour point and flash point makes fish oil

much easier to handle or burn than #6 Bunker C.

c) Fish oil should be heated to a minimum of 50 F for pumping and to 120-140 F for combustion. This start-up temperature is considerably lower than that for Bunker C (220 F).

d) We used the existing oil preheating set which is designed for #6 oil. A much smaller unit would be all that is required.

e) The burner may require marginally higher rates of excess air (12.5%) which is less than 5% difference when compared with a #6 Bunker C fuel oil. Combustion air at 88 F.

7. ENERGY CONSERVATION ASPECTS

a) The storage tank temperature is much lower, 50 F, compared to 120 F for Bunker C #6 oil.
b) For energy conservation purposes, fish oil as a fuel requires a much smaller oil preheating system. Fish oil temperature at the burner is approximately 125-140 F where required Bunker C temperature is approximately 190-200 F, giving a savings in Btu's required to preheat.
c) Less H.P. is required to pump this fish oil.
d) Fish oil having less ash content would have less soot build-up on tubes giving better heat transfer.

8. INVENTORY & SHIPPING COSTS SAVINGS

By burning fish oil we reduce our inventory costs and shipping costs.

9. ENVIRONMENTAL IMPACT

The physical and chemical properties of fish oil showed no cause for concern that burning fish oil as a fuel may have an environmental impact. However, stack emissions were checked and it was found there were no visible emissions from the stack while burning fish oil and no odour.

10. CORROSION & SLUDGING

a) The chemical composition of Bunker C #6 oil is high in sulfur, sodium and vanadium, which play a major part in contributing to sludging and corrosion problems in industrial boilers. In the Atlantic Provinces most Bunker C #6 oil has a sulfur content of 2.5-2.7%. Fish oil on the other hand has a sulfur content of .105% and no vanadium; thus sludging and

corrosion are minimal and no sludging or corrosion was noticed during the burning of fish oil. It is possible to implement residual fuel oil inhibitors to combat sludge but with fish oil as a fuel this is not necessary.

b) Fish oil, being low in sulfur and vanadium, would be much less corrosive on stack economizers, which could also be used in regaining some of the Btu loss. Economizers could be used to a much lower stack temperature using fish oil due to its low sulfur content. This would regain some of the efficiency lost due to increased O2 .

c) The flue gas from fish oil is apparently not corrosive. It is certainly much less corrosive than the more sulpherous #6 Bunker C oil. We inserted the probe of an acid Dewpoint meter into the stack to check for possible corrosive acids in the flue gas. Our concern was to try to detect sodium hydrochloric acid in the boiler. This was not the case. With #6 Bunker C we measured a small but detectable rate of acid build-up.

d) Fish oil has approximately .10% water but does not create sludging in storage tanks and can be dispersed by adding fuel oil inhibitors containing emulsifiers.

CHAPTER 5

CAPITAL COST

1. SUMMARY (For detail of each item see Appendix 2)

	ITEM	COST
1.	Install Storage Tank	$ 9,075
2.	Install Fish Oil Piping	10,325
3.	Instrumentation	6,100
4.	Lab Analysis	1,950
5.	Fish Oil (Differential Price)*	6,900
6.	Consultant	2,650
7.	Monitoring Labour	6,500
8.	Design Engineering	2,500
9.	Information Transfer & Report Writing	5,000
10.	TOTAL	$ 51,000

NOTE: * Market Price of Fish Oil = $ 1.25/Gal.
Purchase Price of Bunker C = .95/Gal.
Difference = $ .30/Gal.
Quantity Purchased = 23,000 Gals.
Subsidy = 23,000 Gals. x $ .30/Gal. = $ 6,900

2. FINANCING

1. CREDA (Conservation & Renewable Energy Demonstration Program):

N.B. Provincial Gov't. (20%) = $ 7,650
Federal Gov't (80%) = 30,600
TOTAL = $ 38,250 (75%)

2. Connors = $ 12,750 (25%)
3. TOTAL = $ 51,000

CHAPTER 6

ECONOMICS

1. Introduction

The cost of residual fuel oils such as #6 Bunker C or #2 fuel oil is expected to increase annually, although Bunker C #6 oil is more unpredictable at this moment. For years the cost difference between #6 oil and #2 oil was relatively stable, at approximately $.11-.12/gal. However, due to what seems to be a glut of Bunker C oil plus high inventory cost, there have been several alternative sources from which to purchase Bunker C oil at a reduced cost. This has resulted in a difference/gal. in Bunker C #6 and #2 fuel oil of up to $ .40-.50 in N.B., depending on location.

This uncertain situation makes it difficult to relate the economics of using fish oil as a fuel if we are equipped and burning Bunker C oil. However, we will attempt to show in the tables attached at what point it would become economically feasible to burn fish oil as a fuel. The economics are determined by four factors:

a) Our net cost/gal of fish oil F.O.B. Boiler Room.
b) Our net cost/gal of fuel used at present.
c) The heating value or Btu's/gal of fuel used.
d) Total overall heating efficiency of boiler used.

2. The Situation - December 1, 1982

a) Detail: See Table 6-1.

b) Summary

1. Fish Oil VS Bunker C: Use of Bunker C was more economic in 1982 and would be till 1986.
2. Fish Oil VS #2 Fuel Oil: Use of fish oil was more economic in 1982 with a savings of $8,190 in 1982 if 70,000 gals. of fish oil were burned instead of #2 fuel oil. These savings were predicted to increase to $59,252 by 1986.

3. Conclusions - December 1, 1982

1. Newfoundland:

The results of this report caused us to look at plants using #2 oil and evaluate their conversion to fish oil. Connors has a plant in Isle-aux-Morts, Newfoundland, where the burning of fish oil for fuel shows great promise of energy cost savings. We have applied for and received a grant under the Newfoundland CREDA program to demonstrate burning fish oil in our small 40 h.p. Cleaverbrooks boiler in Isle-aux-Morts. This boiler is used on low pressure for heating. Results thus far are very encouraging. A report will be submitted by March 31, 1984. Several fishing companies in Newfoundland and Nova Scotia have contacted us for information regarding the burning of fish oil and are now burning fish oil for processing and heating.

2. New Brunswick:

In N.B. we are closer to markets for fish oil, and Bunker C #6 oil is considerably less cost/gal. than in Newfoundland where returns on fish oil are much lower than the mainland and fuel costs are higher. Thus, it is still more economical to use #6 Bunker C oil for fuel than fish oil.

4. The Situation: January 1, 1984

a) Detail: See Table 6-2.
b) Summary:

1. Industrial Fish Oil VS Bunker C: Bunker C is vastly superior.
2. Industrial Fish Oil VS #2 Fuel Oil: #2 Fuel Oil is more feasible, but the gap is projected to narrow by 1986.

5. Conclusions: January 1, 1984

1. Newfoundland: Being investigated.
2. New Brunswick: Not economic to burn fish oil.

TABLE 6-1

SITUATION: DECEMBER 1, 1982

1. Cost Comparison of Fish Oil VS Residual Fuel - Dec. 1, 1982

The table below shows the economics in cost/million Btu's using residual fuel cost VS fish oil costs as of December 1, 1982.

FUEL TYPE	HEATING VALUE* Btu's/GAL	COST/GAL.	COMBUSTION EFFICIENCY	COST/MILLION Btu'S **
Ind. Fish Oil	152,000	$ 1.25	80%	$ 10.27
#6 Bunker C	177,876	$ 1.10	81%	$ 7.63
#2 Fuel Oil	162,000	$ 1.35	80%	$ 10.42

NOTES: * See Table 2-1 for source of information.

** $\text{Cost/Gal.} = \frac{\text{Cost}}{\text{Million Btu}} = \frac{10 \text{ Btu}}{\text{Btu/Gal x Efficiency}} \times$

2. The Future: Bunker C #6 VS Fish Oil

BUNKER C #6 OIL IN N.B. *** % INCREASE/YEAR	AVE. COST B.C. #6 OIL	AVE. NET RETURN GOOD FISH OIL**	AVE. NET RETURN INDUSTRIAL FISH OIL*	POTENTIAL ANNUAL SAVINGS
1983 0%	$ 1.05	$ 1.75	$ 1.29	NIL
1984 - 8.8%	$ 1.15	$ 1.75	$ 1.29	NIL
1985 - 8.8%	$ 1.25	$ 1.75	$ 1.29	NIL
1986 - 7.5%	$ 1.35	$ 1.75	$ 1.29	NIL

NOTES: * Based on 1982 Volume = 70,000 Gals.
** Based on 1982 Volume = 272,000 Gals.
*** Federal Government energy agreement of July 1, 1981

3. The Future: #2 Fuel Oil VS Fish Oil

#2 FUEL OIL IN N. B.*** % INCREASE	AVE. COST #2 FUEL OIL	AVE. NET RETURN GOOD FISH OIL**	AVE. NET RETURN INDUSTRIAL FISH OIL *	POTENTIAL ANNUAL SAVINGS****
1983 - 10%	$ 1.50	$ 1.75	$ 1.29	$ 8,190
1984 - 11%	$ 1.66	$ 1.75	$ 1.29	$ 18,697
1985 - 9%	$ 1.81	$ 1.75	$ 1.29	$ 28,546
1986 - 8%	$ 1.95	$ 1.75	$ 1.29	$ 59,252

NOTE: ****: #2 Fuel Oil VS Industrial Fish Oil.

$70 \text{ K Gal} \left(\frac{\$ 1.29}{\text{Gal.}} - \frac{152{,}000}{162{,}000} \times \$ 1.50/\text{Gal} \right) = \$8{,}190$

NOTE: In 1986 = 37,737 from Industrial Oil
+ 21,515 from Good Oil = 59,252.

TABLE 6-2

SITUATION: JANUARY 1, 1984

1. Cost Comparison of Fish Oil VS Residual Fuel - Jan. 1, 1984

The table below shows the economics in cost/million Btu's using residual fuel cost VS fish oil costs as of January 1, 1984.

FUEL TYPE	HEATING VALUE* Btu's/GAL	COST/GAL.	COMBUSTION EFFICIENCY	COST/MILLION Btu'S **
Good Fish Oil	152,000	$ 2.25	80%	$ 18.50
#6 Bunker C	177,876	$ 1.05	81%	$ 7.29
#2 Fuel Oil	162,000	$ 1.38	80%	$ 10.65

NOTES: * See Table 2-1 for source of information.

** $\frac{\text{Cost}}{\text{Cost/Gal.}} = \frac{10 \text{ Btu}}{\text{Million Btu}} \times \frac{}{\text{Btu/Gal x Efficiency}}$

2. The Future: Bunker C #6 VS Fish Oil

BUNKER C #6 OIL IN N.B. *** % INCREASE/YEAR	AVE. COST B.C. #6 OIL	AVE. NET RETURN GOOD FISH OIL**	AVE. NET RETURN INDUSTRIAL FISH OIL*	POTENTIAL ANNUAL SAVINGS
1984 - 3%	$ 1.08	$ 2.25	$ 1.69	NIL
1985 - 9%	$ 1.18	$ 2.25	$ 1.69	NIL
1986 - 9%	$ 1.29	$ 2.25	$ 1.69	NIL

NOTES: * Based on 1984 Volume = 70,000 Gals.
** Based on 1984 Volume = 272,000 Gals.
*** Federal Government energy agreement of June 30/83

3. The Future: #2 Fuel Oil VS Fish Oil

#2 FUEL OIL IN N. B.*** % INCREASE	AVE. COST #2 FUEL OIL	AVE. NET RETURN GOOD FISH OIL**	AVE. NET RETURN INDUSTRIAL FISH OIL *	POTENTIAL ANNUAL SAVINGS****
1984 -	$ 1.38	$ 2.25	$ 1.69	NIL
1985 - 9%	$ 1.50	$ 2.25	$ 1.69	NIL
1986 - 8%	$ 1.62	$ 2.25	$ 1.69	NIL

NOTE: ****: #2 Fuel Oil VS Industrial Fish Oil.

CHAPTER 7

INFORMATION TRANSFER

From December/82 to May/83 numerous information transfer activities served to inform the general public and those with a direct interest in the project. At least four radio interviews and two television reports were aired, and at least six newsaper articles were printed.

CHAPTER 8

CONCLUSIONS

Chapter 4 presents the results of the experiments:

1. BTU/GAL. A loss of 18.45% in Btu/Gal compared to #6 Bunker C was measured and verified theoretically.

2. CONVERSION COST FROM BUNKER C TO FISH OIL

When converting from #6, #5 or #4 fuel oil to fish oil there should be no conversion costs and only minor burner adjustments required. Only minor changes need to be made in proper air to fuel ratio, fuel temperatue and atomization.

Modifications required to burn fish oil:

a) When boiler is equipped to burn #6 oil all that is required is to:

   1. Set oil preheat temperature to 120-140 F.
   2. Increase excess air approximately 5%.

b) When boiler is equipped for light oil only, an oil preheater should be installed to maintain 120-140 F.

3. TYPE OF BOILER WHICH CAN BE USED

Fish oil can quite easily be used as fuel in a water tube boiler, firetube boiler or fishmeal dryer. Fish oil can be burned in most industrial boilers equipped with either natural draft steam atomizing, rotary cup, air atomizing forced draft or steam atomizing forced draft conventional burners.

4. COMBUSTION CHARACTERISTICS

a) The oil lights well and burns well.
b) The combustion equipment required to burn fish oil is minimal compared to Bunker C #6. The high viscosity and lower pour point and flash point makes fish oil much easier to handle or burn than #6 Bunker C.
c) Fish oil should be heated to a minimum of 50 F for pumping and to 120-140 F for combustion. This start-up temperature is considerably lower than that for Bunker C (220 F).
d) The burner may require marginally higher rates of excess air (12.5%).

5 ENVIRONMENT IMPACT: None

6. CORROSION AND SLUDGING

Fish oil is very low in impurities (sulfur, sodium, vanadium) compared with Bunker C oil which is high in sulfur, sodium and vanadium, which play a major part in contributing to sludging and corrosion problems in industrial boilers.

Chapter 5 presents the details of the project's Capital Cost of $51,000. The financing of the project was CREDA (75%) = $ 38,250 and Connors (25%) = $ 12,750. The cost of this project was partly in precautions taken to protect boilers from possible damage from the unknown or interruptions in fishmeal process if boilers should happen to fail. Many actions taken above would not be necessary now that this study has highlighted areas of concern to industry.

Chapter 6 presents the economics. When we first looked at the economics in December 1, 1982 we concluded:

1. Fish Oil VS Bunker C: Bunker C was more feasible in 1982 and would be till 1986.
2. Fish Oil VS #2 Fuel Oil: Fish Oil was more feasible in 1982 with a savings of $ 8,190 in 1982 if 70,000 gals. of fish oil was burned istead of #2 oil. These savings were predicted to increase to $ 59,252 by 1986.

Thus we investigated switching from #2 fuel oil in Isle-aux- Morts, Newfoundland to burning fish oil. In N. B. we are closer to markets for fish oil, and Bunker C #6 oil is considerably less cost/gal. than in Newfoundland where returns on fish oil are much lower than the mainland and fuel costs are higher. Thus, it is still more economical to use #6 Bunker C oil for fuel than fish oil.

However, the situation in January 1, 1984 is much different from December 1, 1982 because of the decline in fuel oil prices and the increase in herring oil prices, thus:

1. Industrial Fish Oil VS Bunker C: Bunker C is vastly cheaper.
2. Industrial Fish Oil VS #2 Fuel Oil: #2 Fuel Oil is more feasible, but the gap is projected to narrow by 1986.

Several fishing companies in Newfoundland and Nova Scotia with fishmeal plants using oily fish (herring) have contacted us for information regarding burning fish oil and were burning fish oil for processing and heating. They have since stopped due to the sudden increase in fish oil price.

In conclusion, we found fish oil to be a viable technical alternative to residual fuel oils. In most cases, minor adjustments to fuel temperature and air supply is all that is required. Although there is an 18% heat loss when using fish oil as a fuel, its physical and chemical properties show that some of these losses could be retrieved. To use fish oil as a fuel in the future is a definite alternative providing fuel prices prove it economically feasible.

CHAPTER 9

RECOMMENDATIONS

1. Experiment with Fish Oil (blended with diesel fuel) for diesel engines; when economics permit.

2. Finalize Isle-aux-Morts report on burning fish oil in a 40 h.p. Cleaverbrooks boiler.

APPENDIX 1

TECHNICAL BACKGROUND - DETAILS

Appendix 1-1: Description of Fishmeal Process - #3 Fishmeal Plant
Appendix 1-2: Bunker C Combustion Theory - Detail

FIGURE A1-1

The operation of a typical

FISHMEAL AND FISHOIL PLANT

A Hasher
B Feeder
C Cooker
D Strainer conveyor
E Twin-screw press
F Tearing machine
G Drier
H Vibration strainer with magnetic separator
J Milling plant
K Automatic weighing machine
L Deodorizing plant
M Steam boiler
N Desludging machine
O Press water centrifuges
P Oil polishing centrifuge
R Concentrating plant

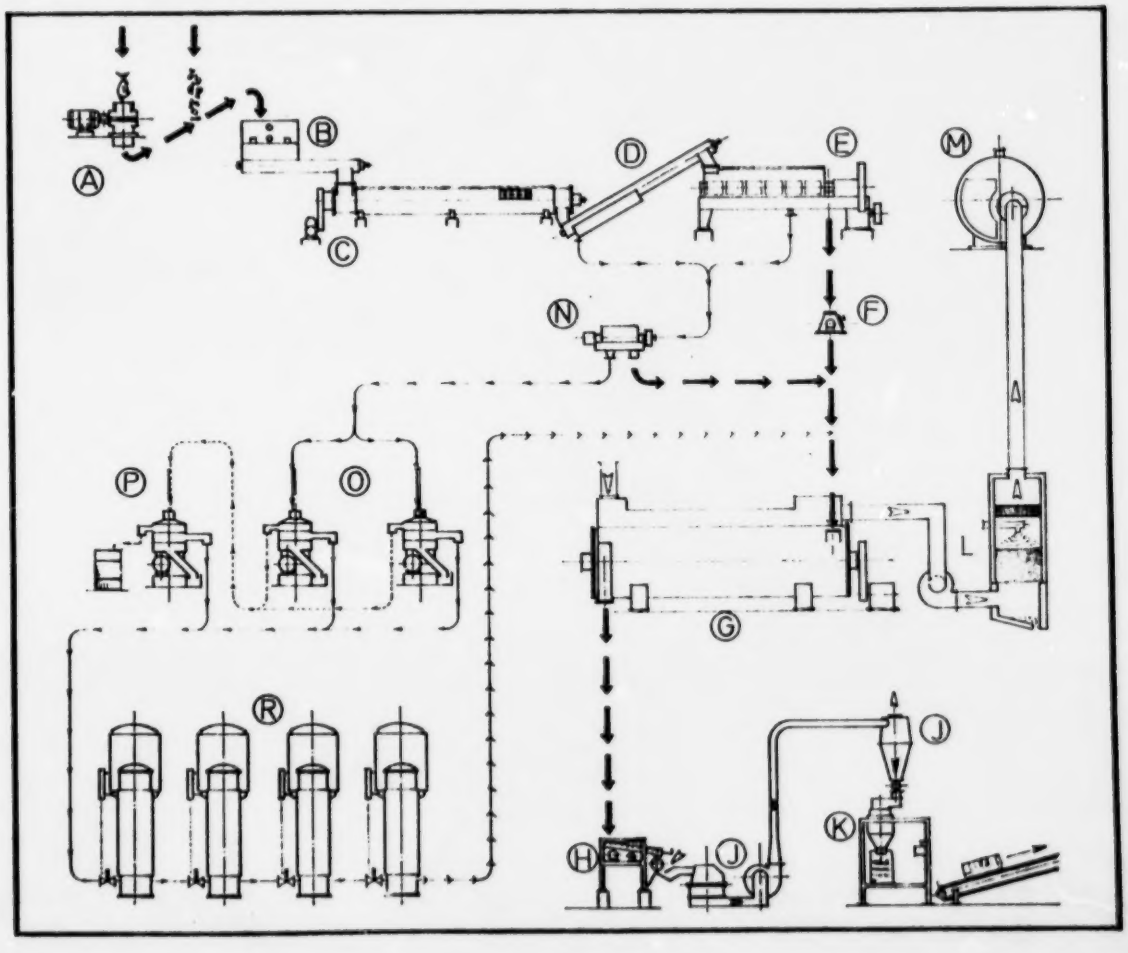
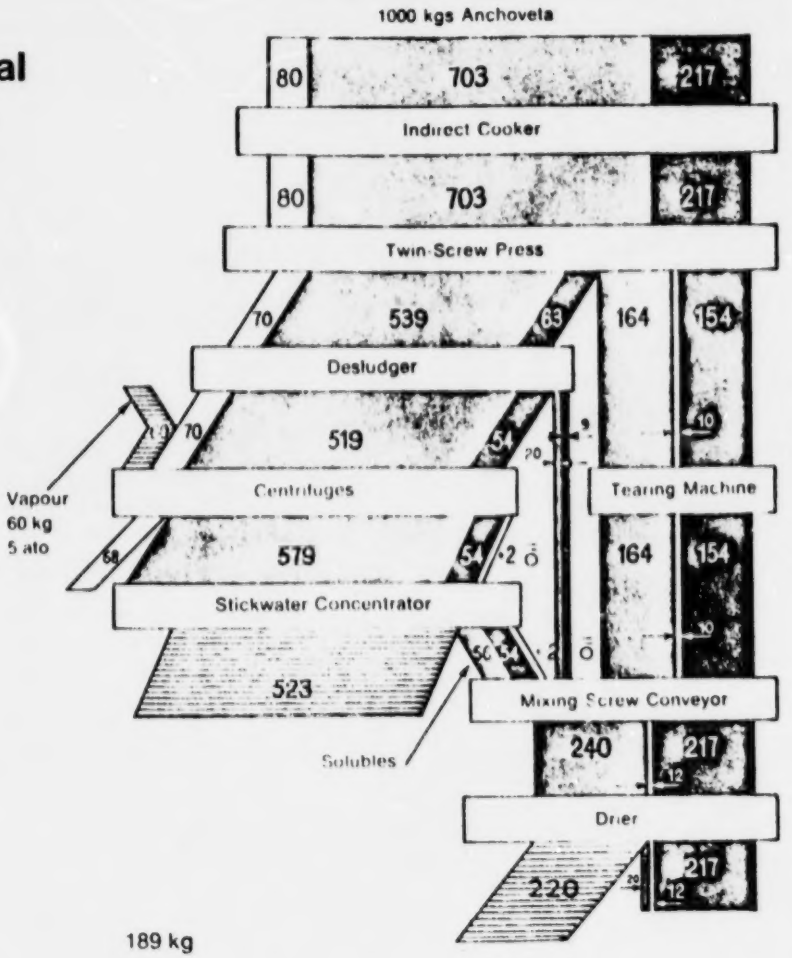


FIGURE A1-2

Diagram of a Fishmeal and Fishoil Plant with Stickwater Plant



Fishmeal:

Without stickwater:	189 kg
With stickwater:	249 kg
Water content:	8 %
Fat content:	5-8 %

ATLAS STORD

Output is raised by 20-30 per cent when the STICKWATER is utilized.

The process may vary with the nature of the raw material but in broad outline it is as follows:

Large fish are cut into suitable pieces in a hashing machine. The material is then fed into the cooker for indirect steam processing. From the cooker it passes by combined strainer and screw conveyor to the twin-screw press, which removes the main part of the oil and water. The press cake is then disintegrated in a tearing machine, dried in a special ATLAS-STORD drier and passed through a vibrator strainer incorporating a magnet, to be ground to meal, weighed, and finally bagged.

The press water is treated as follows:

Insoluble dry matter is removed by means of a special decanter, the oil is extracted by centrifuges, the oil-free stickwater which remains is evaporated in a concentrating plant and returned in the form of concentrated stickwater to the driers, where it is mixed with the press cake to produce the so-called whole meal.

APPENDIX 1-1

DESCRIPTION OF FISHMEAL PROCESS

#3 FISHMEAL PLANT

The raw material is shipped from various plant locations by truck and boat. After being pumped from the two separate unloading stations, the raw material passes over rotary screens, the pump water is collected into a holding tank and the remainder is placed in holding bins. From the bins, the fish is placed by mechanical bucket loaders into hoppers and transported to the cookers by screw conveyors.

In the cooker, the fish is cooked by heat transferred indirectly through the steam heated surfaces of the rotor and the steam jacketed shell, and, if necessary, also by direct steam through a system of jets.

The processing in the cooker lasts for 15-20 minutes, during which period the temperature necessary for coagulation of proteins is reached. The liquid (water and oil) is subsequently partly removed in a perforated prestrainer located in the screw conveyor that feeds the screw press.

The screw press removes a further quantity of water and oil, discharging the remaining solids, the presscake, to a screw conveyor, then to the dryers. The two dryers are installed in series and the semi-dried material from the first dryer is transported to the second dryer by a fan into a cyclone and into a screw conveyor in which stickwater concentrate is added before the meal enters the final drying stage.

From the second dryer, the meal is transported by circulating fan to a cyclone from which it is discharged and conveyed to the sifting and grinding station. From here, the meal is transported by screw to an automatic scale and bagging station. The bags are palletized and stored in warehouse to await shipment.

The mixture of oil and water, the press liquid, from the prestrainer and the press is passed through a pump and over vibrating screens for removal of suspended solids. The solids are retured for reprocessing into the main product line flow before entering the press, while the liquid is pumped to holding tanks. After preheating in the tanks, the press liquid is pumped to the centrifuges for separation into oil and stickwater. Oil is then transferred by pump to the main storage tank farm system and ready for sale and shipment.

The stickwater is pumped from the first separator to a tank, preheated and fed to a four-stage evaporator for concentration. From the stickwater evaporating plant, the concentrate (solubles) are transported to the second dryer where they are added and mixed with the semi-dried meal.

This process is best explained in the attached diagrams Figure A1-1 and Figure A1-2.

APPENDIX 1-2

BUNKER C COMBUSTION - THEORY

1. INTRODUCTION

The most common fuel used today in large industrial boilers is #6 Bunker C. Although the technology required to burn this oil is much more complex than more refined oil, the economic advantages outweigh the disadvantages of higher technology.

The technology involved may be divided into the following classifications, which will then be discussed individually:

a) Physical and chemical properties of residual oil.
b) Combustion equipment.
c) The combustion process.

2. PHYSICAL & CHEMICAL PROPERITES OF RESIDUAL OIL

We will first examine the physical and chemical properties of #6 oil which will greatly determine the combustion equipment required and the combustion procedure to follow.

Residual fuels such as #6 Bunker C are a by-product of a refinery operation where light fractions such as gasoline, kerosene and lubricating oils have been distilled. The residue remaining in the stills plus residue drawn off the bottom from the vacuum tower are blended with a cutter stock to correct their viscosity and is sold as a residual fuel oil.

It should be noted that the physical properties and chemical composition can vary appreciably, depending on the source of crude oil and the refining operation.

Bunker C is widely accepted and used in industrial operations today, due mainly to its low cost and high Btu content. Bunker C is a black viscous fuel oil which requires rather expensive preheating equipment in order to burn properly. The chemical composition of Bunker C #6 oil is high in sulfur, sodium and vanadium, which play a major part in contributing to sludging and corrosion problems in industrial boilers.

3. COMBUSTION EQUIPMENT

When burning #6 Bunker C oil it is important that we have well designed and properly maintained combustion equipment. This will play a major part in obtaining maximum boiler efficiency. It also retards boiler sludge deposits and corrosion attacks.

The viscosity of this fuel entering the burner must be closely controlled for proper operation. If the oil temperature is too low at the burner tip, the result is poor atomization and incomplete combustion. These unburned sticky oily particles adhere to the furnace tubes and collect fly ash to form sludge deposits.

High oil temperature will vaporize the fuel oil and combustion takes place near the burner tip causing warping of burner equipment and erosion of burner area refractory.

Proper air and oil ratio is very important for more efficient combustion.

4. THE COMBUSTION PROCESS

Residual fuels consist of a mixture of hydrocarbons of various types together with organic complexes of sulfur and vanadium. Complete combustion requires excess air so that unburned hydrocarbons, carbon and carbon monoxide are prevented from forming.

If perfect combustion was possible the maximum percent of carbon dioxide (CO_2) would be 15.6%. In actual fact a safety factor of approximately 30% excess air is allowed, leaving a range of 11-13% CO_2 in the flue gasses.

APPENDIX 2

CAPITAL COST - DETAIL

Appendix 2-1: Individual Capital Cost
Appendix 2-2: Portable Combustion Optimizer
Appendix 2-3: Sootamatic

APPENDIX 2-1

INDIVIDUAL CAPITAL COST

1. Install Storage Tank ($ 9,075)

The first step in this project was to install a 15,000 gals storage tank (used) for storing and blending fish oil and Bunker C #6 oil. It was our intention to burn a blend of 25% fish oil, 50% and 75%, according to the results of combustion. In June, 1982 a concrete pad was run and the 15,000 gals tank was delivered and set up. A proper safety bunker was installed for pollution control. For location of tank and piping see Figure 2-1.

2. Install Fish Oil Piping ($ 10,325)

Step two consisted of an independent oil delivery system for proper blending and control. It was essential that we not interrupt the fishmeal operation for long periods of time necessitating an independent system so that the fish oil supply could be cut off if problems arose and not bother the fishmeal operation. The new piping arrangement allowed us to store oil produced and burn quantities preferred, according to combustion results. A new oil supply and return line was installed from the new tank including all necessary valves, gauges and pumps.

Step three involved monitoring of the project. In order to collect accurate data we doubled all temperature and pressure gauges ($ 525) and purchased electronic tank level gauge from Brian Engineering of Halifax for measuring fuel used. An in-line Neptune flow meter was also used. Until the most efficient operating temperature of oil was established and oil pressure required for the burning of this fish oil, it was necessary to go to these extremes.

3. Instrumentation

1. Portable Combustion Optimizer ($ 3,200): (Flue Gas Analyzer)

We purchased a portable combustion optimizer from Neotronics N A Inc. for continued monitoring of combustion efficiency. For further details on this unit see Appendix 2-2.

2. Sootamatic ($ 2,900):

A sootamatic for cleaning boiler tubes and obtaining soot samples was purchased and used during boiler shutdowns. See Appendix 2-3.

4. Lab Analysis ($ 1,950)

Had several samples of fish oil analyzed in professional Labs for physical and chemical properties. See Table A1-1 for results.

5. Fish Oil (Differential Price) = $ 6,900

Market Price of Fish Oil = $ 1.25/Gal.
Purchase Price of Bunker C = .95/Gal.

Difference = $ .30/Gal.

Quantity Purchased = 23,000 Gals.
Subsidy = 23,000 Gals. x $ .30/Gal. = $ 6,900

6. Consultant ($ 2,650)

We hired a consultant (Jim Hall) with the instrumentation required to do a professional combustion analysis and issue a report of his results. See attached Consultant's report, Appendix 2.

7. Monitoring Labour ($ 6,500)

We had boiler operators take hourly readings on boiler performance for 1 month and log findings.

8. Design Engineering ($ 2,500)

9. Information Transfer and Report Writing ($ 5,000)

All data was collected and analyzed for final report. Monthly progress reports were published and Final Report written.

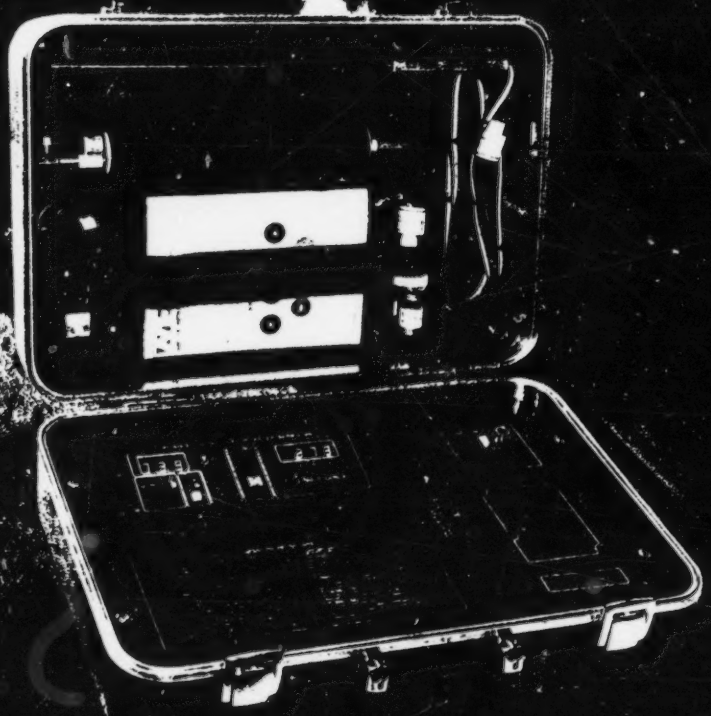
10. TOTAL = $ 51,000

APPENDIX 2-2

Neotronics Energy Conservation Division

PCO

PORTABLE COMBUSTION OPTIMIZER



Fuel Savings — Neotronics Know How

The Neotronics PCO Portable Combustion Optimizer 960-1

RIGHT NOW you can reduce the cost of accurately setting boiler and furnace controls by using the PCO (Portable Combustion Optimizer) from Neotronics!!

Whether you are an O.E.M. with commissioning engineers, a servicing company with field engineers or a major fuel user with your own maintenance staff, the PCO will help you increase your profitability.

Neotronics Know-How now gives you the first continuous display combustion analyzer specifically designed for the professional combustion engineer. It provides "real-time" continuous display of all the stack gas parameters needed to set burners for all types of fuel for maximum efficiency compatible with safe and trouble-free boiler operation.

What the PCO Measures for YOU!

A clear high brightness digital display, easy to read under all lighting conditions shows:

Stack Oxygen concentration from 0% to 20.9% Oxygen in 0.1% steps. This output is a direct indication of fuel air ratio and supercedes the measurement of Carbon Dioxide by less accurate chemical methods.

Stack Carbon Monoxide concentration from 0-3999 Parts Per Million in 1 ppm steps. Carbon Monoxide is an invaluable indicator of the fuel air mixing characteristics of an installation and in many countries is a mandatory measurement on gas-fired installations.

Stack Differential Temperature (stack gas temperature less ambient temperature) from 25 C to 999 C. This measurement provides a clear indication of the heat transfer performance of the installation.

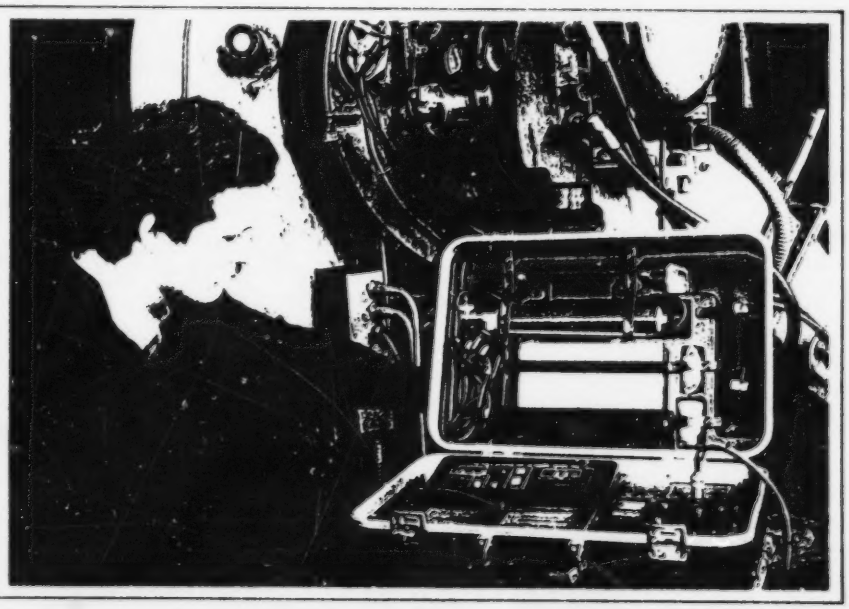
Combustion Efficiency for fuel oil, coal and natural gas, continuously displayed in 0.1% steps. The final proof that the furnace or boiler is correctly set for maximum efficiency related to its design.

Stack Soot Density on oil fired installations may additionally be measured by the pump, test papers and soot comparator chart supplied with the PCO

The PCO is a powerful tool to help engineers to improve the efficiency of most boilers and furnaces whilst ensuring that this is not achieved at the expense of installation life, long term performance or atmospheric pollution.

Description

The PCO (Portable Combustion Optimizer) is a complete flue gas analysis system mounted in a compact and robust attache case. It continuously measures flue gas temperature, Stack Oxygen and Carbon Monoxide content whilst simultaneously calculating and displaying the percentage combustion efficiency associated with excess air conditions. The extended flexible probe allows the engineer to observe changes in combustion pattern whilst simultaneously adjusting burner controls.

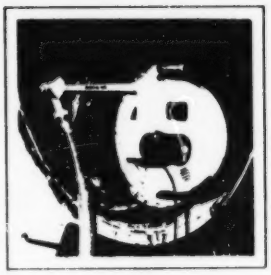


The PCO being used to monitor combustion changes during burner adjustment.

INDEX

SOOT-A-MATIC®

for firetube boilers



Pages 2-6

Soot-A-Matic is a lightweight, compact boiler tube cleaning system. One man can simply and thoroughly clean a boiler in a fraction of the time required for outmoded cleaning methods — all by pushing a trigger. Soot-A-Matic has an integrated vacuum which collects soot and scale as it is removed from the firetubes by Soot-A-Matic's interchangeable cleaning brushes.

REAM-A-MATIC®

Model RAM-3X

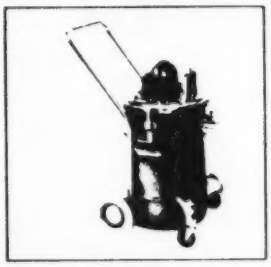
for tubes/pipes 1"-up

Pages 10-11

Ream-A-Matic 3X incorporates a 1 HP drive motor and is designed for use with a ½" diameter flexible shaft for removing deposits in tubes 1" and larger. It can be used with a continuous water flush or in conjunction with a vacuum for simultaneous removal of dry deposits. Special cutting tools available for both straight and curved tubes.

VACUUMS

for plant maintenance

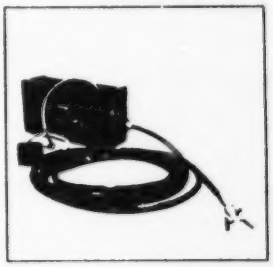


Page 5

Goodway vacuums are powered for strong suction for use in cleaning boilers or any maintenance application. Four reliable units available with self contained mobile tank and/or adapters for standard drums.

AWT-100

for watertube boilers and other curved or straight tubes



Pages 12-15

The AWT-100 air powered tube cleaner is used for all types of tube cleaning applications where brushing or cutting of tube deposits with simultaneous water flushing action is desirable. The variable torque and speed controls allow the use of a complete range of flexible shafts for tube I.D.'s ¼" to 10".

REAM-A-MATIC®

Model RAM-3

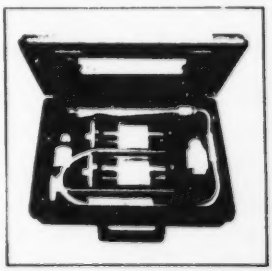
for condensers, heat exchangers, etc. ¼"-1" tubes

Pages 7-9

Ream-A-Matic makes tube cleaning a simple one man operation. Ream-A-Matic uses a flexible shaft to snake through the tubes. The rotating action of the cable allows the cleaning brush or cutting tool to loosen all deposits along the way. Water transported through the shaft simultaneously and continuously flushes out the loosened deposits, leaving the tubes thoroughly cleaned.

TESTER

for boiler efficiency

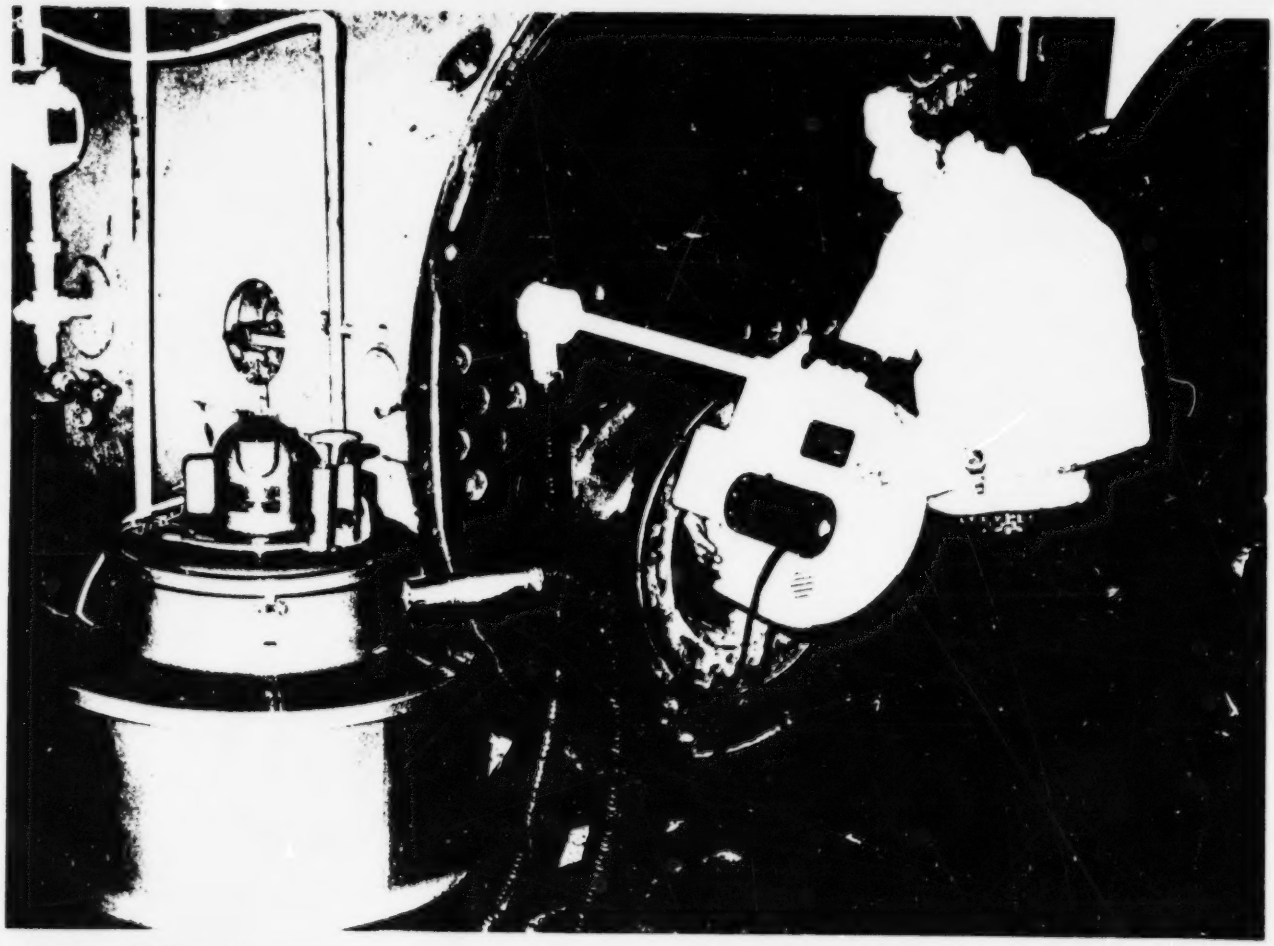


Page 16

The Goodway Boiler Efficiency Tester makes it easy for anyone to determine if a burner needs adjustments or the boiler needs to be cleaned. Testing components include CO_2 and O_2 analyzers, absorption fluids, sampler pump, thermometer, smoke indicator, and combustion efficiency rule. By performing these simple tests on a regular basis and by taking appropriate action to maintain maximum boiler efficiency, many heating dollars can be saved.

SOOT-A-MATIC

MODEL SAM-2 BOILER TUBE CLEANING SYSTEM



FUEL SAVINGS

Many products claim to save fuel, but one thing you know for sure is that if tubes are dirty, fuel is wasted. The one proven way to improve boiler efficiency is to keep the tubes clean. The Soot-A-Matic is the easiest way to do this.

COMPACT

Close quarters in many boiler rooms make it impossible to use a cleaning rod the length of the tube. Soot-A-Matic requires only 4' clearance and can clean from either end of boiler.

SANITARY

With the simultaneous vacuum feature, Soot-A-Matic leaves no room for soot to escape into the atmosphere, thus leaving the boiler room and maintenance personnel clean when the job is done.

LABOR SAVINGS

The Soot-A-Matic enables one man to clean a boiler in a fraction of the time required for out moded methods. Cleans a tube in 20-30 seconds.

DOWNTIME SAVINGS

The Soot-A-Matic can be used on a hot boiler. When it is important that the boiler be down for a minimum period, the Soot-A-Matic can do the job quickly.

APPENDIX 3

CONSULTANT'S REPORT

FISH OIL EVALUATION

AT

CONNORS BROS., LIMITED

BLACKS HARBOUR, N. B., E0G 1H0

FOR

FRANK STEVENS

ENERGY CO-ORDINATOR

BY

JAMES HALL, B.A., C.E.T.

TECHNICAL OFFICER

CARVERN PETROCHEMICAL CO., LIMITED

1. INTRODUCTION

Between September 7, and October 14, Connors Brothers conducted an evaluation of the combustion of fish oil in boilers at their #2 Plant in Blacks Harbor, New Brunswick.

During this time a total of 12,108 gallons of fish oil was burnt in 2 boilers as described in Appendix B.

During this same period of time, 15,693 gallons of #6C oil from Irving was burnt and data taken for comparison with the fish oil.

2 samples of fish oil were taken for analysis and an average analysis is as follows.

FISH OIL ANALYSIS

Heating Value	-	152,000 BTU/Imp. Gal.
Specific Gravity	-	23.3° API
Density	-	9.14 lb/Imp. Gal.
Heating Value	-	16,632 BTU/lb.
Flash Point	-	219°F
Pour Point	-	31°F
Water Content	-	3.5%
Salt Content	-	1.22%
Ash Content	-	.005%
Sulphur Content	-	.105%
Carbon Content	-	77.54%
Hydrogen Content	-	11.76%
Other Components	-	5.87%

NOTE:

This is an unrefined fish oil.

1. INTRODUCTION (Cont'd):

There is a small amount of water and sodium chloride in the fish oil. This occurs as a result of the handling process of the fish. The fish are brought in by boat packed in salt and ice and some of this carries through the fish meal process and finds its way into the fish oil that is extracted. Ash content is very low and sulphur is minimal.

2. HEAT CONTENT OF FISH OIL

Normal heat content of a #6 oil is 18,300 BTU/lb. (see Appendix C). This means that the heat content of the fish oil is reduced by:

$$\frac{18,300 - 16,632}{18,300} \times 100 = 9.1\%$$

Therefore, there is a reduction in the heat content of the fuel by 9.1% on a weight basis.

Normally, the density of #6 oil will vary 9.22 lbs/gal. to 10.22 lbs/gal. with the average being 9.72 lbs/gal. If we consider the difference in density, then the loss of heat content of the fish oil becomes much greater.

$$\frac{18,300 \times 9.72 - 16,632 \times 9.14}{18,300 \times 9.72} \times 100 = 14.54\%$$

Therefore, there is a loss of heat content in the fish oil of 14.54% when compared with #6C oil on a volume basis.

From a visual inspection of fish oil it can be seen that it is liquid at room temperature, it is dark in colour and has a characteristic odour of fish. In visual appearance, it is quite similar to #4 fuel oil. Average specifications for #4 oil are:

Gravity	-	15 - 30° API
Density	-	8.76 to 9.66 lb/gal.
Pour Point	-	- 10 to + 50°F
Heating Value	-	18,280 to 19,400 BTU/lb.
Sulphur	-	.8%
Water & Sediment	-	trace to 1.0%

2. HEAT CONTENT OF FISH OIL (Cont'd):

It can be seen that with the exception of the heating value, the fish oil and the #4 oil are quite similar. The reason for the lower heating value is the low carbon content of the oil. Fish oil contains only 77.54% carbon while a fuel oil contains approximately 10% more carbon. As carbon contains 14,500 BTU/lb. 10% more carbon would increase the heating value of the fish oil to:

$$16,632 + 1450 = 18,082 \text{ BTU/lb.}$$

which would put it in the range of a fuel oil.

3. FISH MEAL DRYER EVALUATION

During the evening of September 7, the fish oil was burnt for approximately 10 minutes in one fish meal dryer of Plant 2, with a steam atomizing natural draft burner. Fish meal dryers are of the rotary furnace type where the processed product comes directly in contact with the hot gases of combustion.

During this short trial, there was no fish meal in this dryer so load on the burner had to be kept low to prevent overheating the unit. Lite-off occurred immediately and the flame was quite stable. No measurements were taken other than visual observations.

Throughout the fish oil trials, the fish oil was often burnt in the two fish meal dryers for several hours at a time, but, no attempt was made to do any scientific calculations for the combustion as these dryers are quite open, it is difficult to control the air flow, and instrumentation on them is minimal. The two dryers are quite similar except that one has a North American steam atomizing burner and the other has a Ray Rotary cup burner. Fish oil was burnt in both with no visual problems.

4. BOILER EVALUATION:

On Thursday, September 9, fish oil was lite-off in the Cleaver Brooks CB 621-200 boiler. Total time of operation was less than one hour. That evening, fish was lite-off in the Volcano WS-35 boiler. Lite-off was immediate and the boiler ran throughout the night on fish oil with no visual problems.

On September 10, 1982, a A.S.M.E. abbreviated efficiency test was conducted on the Volcano boiler using the heat loss procedure.

INSTRUMENTS USED

The portable instruments used for this evaluation included:

- Combustion Instruments Model 59 Dual Flue Gas Analyzer for oxygen and carbon monoxide.
- Thermco Model P-11 Flue Gas Analyzer for carbon dioxide.
- Thermo Electric Mini-mite Temperature Millivolt Potentiometer with type K thermocouple
- Bacharach Sling Psychrometer
- Bacharach Smoke Tester #21-7006

Detailed specifications of the electronic instruments are given in Appendix E. Pressure and temperature of water and fuel were taken from instruments mounted on the boiler. The efficiency of the boiler was found to be 80.02% at 50% steam flow. This efficiency is measured on a BTU basis. Therefore, the fish oil may have a lower heat content, so more oil is required, but, 80.02% of the heat content is converted into steam.

4. BOILER EVALUATION (Cont'd):

By comparison, I tested this boiler on February 13, 1982, burning #6C oil and found the efficiency to be 81.74% at approximately the same load. This means that there has been a drop of 1.72% in efficiency from the #6C oil to the fish oil.

It should be noted that this boiler has a very efficient Todd Burner that will run with less than 1% oxygen in the flue gas when burning #6C oil.

This is a best case of combustion of #6C oil. When the boiler is on automatic control, the oxygen content of the flue gas must be increased to in excess of 1% to increase the combustion air slightly to over 2% oxygen in the flue gas with the fish oil to prevent smoking.

The net result was that the oxygen content of the gas must be increased by at least 1% when burning fish oil to prevent smoking.

This boiler does not have an in-stack oxygen analyzer with trim system, so all oxygen readings were taken with the combustion instruments Model 59 Analyzer with the boiler controls set in manual operation. During this testing, the preheat temperature of the fish oil was varied from 100°F to 160°F. By visual observation of the flame, it was determined that 140°F was quite a satisfactory temperature for combustion.

The fish oil has a pour point of approximately 31°F so it is necessary to provide some heat to the storage tanks in winter to keep the fish oil above the 31°F for pumping. Probably the tanks should be kept at 50-55°F for pumping the oil and then the oil heated to 120° to 140°F for combustion.

5. FIRETUBE BOILER EFFICIENCY:

The Cleaver Brooks Firetube Boiler was run for several days on fish oil. This boiler is a standby boiler and not normally used for production steam so it did not receive the running time that the Volcano boiler did. It was found that it was necessary to open the valve on the atomizing air to the maximum open position for proper combustion. On #6C oil, this valve had been slightly closed.

Oxygen content of the flue gas on this boiler was set at 3% at maximum firing rate and 6% at minimum firing rate. This is slightly higher than is possible with a #6C oil. Other parameters were about the same for both fish oil and #6C fuel oil.

Detailed calculations of efficieny were not made as there was not sufficient running time on this boiler.

6. CORROSION TESTING:

While evaluating the fish oil, the probe on a Land Model 200 Acid Dewpoint Meter was inserted into the flue gas. The Land Dewpoint Meter is calibrated for detection of sulphuric acid in the flue gas, and the tip can be cooled with compressed air to bring its temperature below the dewpoint temperature and so induce condensation of the liquid.

As the fish oil contains a small amount of sodium chloride, it was decided to see if the sodium chloride was disassociating and forming hydrochloric acid at the exit of the boiler.

Although the dewpoint meter is calibrated for sulphuric acid, the tip will sense all acids and pass a current if they are present.

During the operation of the boiler with fish oil, no acids were detected by the dewpoint meter. At no time did any current register on the dewpoint meter, even though the tip was cooled to temperatures less than $200^{\circ}F$. Therefore, we can only conclude that there was no disassociation of the salt at these concentrations and insufficient quantities of sulphur to cause corrosion under these operation conditions.

6. CORROSION TESTING (Cont'd):

On February 13, 1982, I tested this boiler for rate of acid build-up using a Irving #6C oil with approximately 2.7% sulphur. At this time, there was a small but detectable rate of acid build-up. At approximately 50% load on the boiler with a tip temperature of 250°F, the rate of acid build-up was 20 uamps/min. At a tip temperature of 210°F, rate of build-up was 60 uamps/min. Acid dewpoint was 270°F.

Rates of build-up less than 100 uamps/min. are not considered seriously corrosive* While these readings were taken the boiler was always operating at less than 10% excess air and this may account for the low rate of build-up.

* A.S.M.E. Paper 63-4A-108, Clark & Childs, 1963.

7. OPERATING RECORDS:

From September 10 to October 14, Connors personnel kept records of the oil consumed versus steam produced and a summation is given in Appendix A.

Steam flow was not recorded on 4 days: SEptember 11, 13 and October 12, 13.

On the 8 days the fish oil was burnt and steam flow recorded, 8772.4 gallons of fish oil produced 105,927.5 lbs of steam or:

$$\frac{105,927.5}{8772.4} = 120.75 \text{ lbs of steam per gal. of oil}$$

On the 13 days that #6C oil was burnt and steam flow recorded, 14,273.25 gallons of oil produced 2,113,313 of steam or:

$$\frac{2,113,313}{14,273.25} = 148.06 \text{ lbs of steam per gallon of oil}$$

This means that there is a net loss of steam production of:

$$\frac{148.06 - 120.75}{148.06} \times 100 = 18.45\%$$

This is consistent with our heat loss calculations as there is a 14.54% loss of heat content of the oil on a volume basis and a 1.72% loss of efficiency in the boiler.

8. CONCLUSIONS:

- Fish oil may be burnt using any type (natural draft steam atomizing), rotary cup, air atomizing forced draft, steam atomizing forced draft) of conventional burner.

- Fish oil can quite easily be used as fuel in a water tube boiler, firetube boiler or fish meal dryer.

- Fish oil should be heated to a minimum of 50°F for pumping and to 120 to 140°F for combustion.

- The combustion characteristics of fish oil are similar to #4 fuel oil.

- There is a noticeable loss in heat content of approximately 15% when fish oil is compared to a #6C fuel oil on a volume basis.

- There is a small loss in combustion efficiency of approximately 2% due to the higher flows of combustion gas due to the lower heat content of the oil.

- The burner may require marginally higher rates of excess air (less than 5% when compared with a #6C fuel oil).

- The flue g from fish oil is not corrosive and is much less corrosive than #6C . amounts of sulphur.

- As there is a lower heat content of the fish oil, it will require more fish oil to produce the same amount of steam as with #6C oil. If the oil pumping system cannot deliver enough oil, or the fan cannot deliver enough air, it may limit the maximum output of the boiler to a lower quantity of steam than with #6C fuel oil. It may derate a unit by as much as 18%.

APPENDIX A

SUMMATION OF DATA TAKEN BY CONNORS OPERATORS

OIL CONSUMED VERSUS STEAM PRODUCED

DATE	FISH OIL CONSUMED GALLONS	#6C OIL CONSUMED GALLONS	RUNNING TIME HOURS	STEAM PRODUCED LBS.
SEPT. 10	1427		10.5	196,500
11			3	
13		1420	13.5	
14		890	12	167,500
15		1960	15	252,500
16		1100	13	197,000
17		1340	12	219,000
20		1037	11.75	179,188
21		1007	10.00	154,000
22	920		11.66	146,275
23	864		11	130,000
24	1210		12.00	177,000
27		241	3.5	43,000
28		1054	10	126,125
29		1737	13.5	183,000
30		1544	10	153,000
OCT. 1		1178	13	199,500
4		720	11	123,000
5	1218		10	106,500
6		965.25	10	116,500
7	1440.5		13	151,500
8	1692.9		10	151,500
12	475.2			
13	831.6		14	
14	1559.3		13	169,000
TOTAL	12108.5	15,693.25	266.41	3,341,588

APPENDIX B

BOILER SPECIFICATIONS

	BOILER NO.1	BOILER NO.2
MAKE	VOLCANO	CLEAVER BROOKS
MODEL	WS-35 WATERTUBE D-TYPE	CB 621-200 FIRETUBE
BURNER MANUF.	TODD (STEAM ATOMIZING)	CLEAVER BROOKS (AIR ATOMIZING)
YEAR MANUF.	1970	1959
OPERATING PRESSURE	110 PSIG SATURATED	110 PSIG SATURATED
MAX.OUTPUT	35,000 LBS/HR.	200 H.P. 6,695,000 BTU/HR.
OPERATING CONTROLS	BAILEY PNEUMATIC	HONEYWELL ELECTRIC
FUEL	#6C OIL	#6C OIL

APPENDIX C

A.S.M.E. ABBREVIATED EFFICIENCY TESTS

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

SUMMARY SHEET — PTC 4.1-a (1964)

TEST NO — BOILER NO. — DATE Sept 10/52

OWNER OF PLANT: Connors Brothers — LOCATION: Blacks Harbor Plant 2

TEST CONDUCTED BY: J Hall — OBJECTIVE OF TEST: Efficiency — DURATION

BOILER MAKE & TYPE: Volcano WS-35 — RATED CAPACITY 35,000 lb/hr

STOKER TYPE & SIZE

PULVERIZER, TYPE & SIZE — BURNER, TYPE & SIZE: Todd.

FUEL USED: Fish Oil — MINE — COUNTY — STATE — SIZE AS FIRED

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	125
	STEAM PRESSURE AT S. H. OUTLET	psia	
	STEAM PRESSURE AT R. H. INLET	psia	
4	STEAM PRESSURE AT R. H. OUTLET	psia	
	STEAM TEMPERATURE AT ~~S. H. OUTLET~~ Saturated	F	344 F
6	STEAM TEMPERATURE AT R H INLET	F	
7	STEAM TEMPERATURE AT R.H. OUTLET	F	
	WATER TEMP. ENTERING (ECON.) (BOILER)	F	220
9	STEAM QUALITY % MOISTURE OR P. P. M.		
	AIR TEMP. AROUND BOILER (AMBIENT)	F	88
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	88
12	TEMPERATURE OF FUEL	F	140
	GAS TEMP. LEAVING (Boiler) (Econ.) (Air Htr.)	F	520
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	—

UNIT QUANTITIES

	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	315
16	ENTHALPY OF (SATURATED) (SUPERHEATED) STM.	Btu/lb	1191
	ENTHALPY OF SAT. FEED TO (BOILER) (ECON.)	Btu/lb	188
18	ENTHALPY OF REHEATED STEAM R.H. INLET	Btu/lb	—
	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	—
20	HEAT ABS./LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	1003
	HEAT ABS./LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	0
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	—
	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	.7754
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	14.8

HOURLY QUANTITIES

	ACTUAL WATER EVAPORATED	lb/hr	17500
27	REHEAT STEAM FLOW	lb/hr	0
	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	
	TOTAL HEAT INPUT (Item 28 x Item 41) / 1000	kB/hr	
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	
	TOTAL HEAT OUTPUT (Item 26 - Item 20) + (Item 27 x Item 21) + Item 30 / 1000	kB/hr	

FLUE GAS ANAL. (BOILER) (ECON) (AIR HTR) OUTLET

	CO_2	% VOL	13.2
	O_2	% VOL	2.5
34	CO	% VOL	0
	N_2 (BY DIFFERENCE)	% VOL	84.3
	EXCESS AIR	%	12.93

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt		OIL	
37	MOISTURE		51	FLASH POINT, F°	214
38	VOL MATTER		52	Sp. Gravity Deg. API*	23.3
39	FIXED CARBON		53	VISCOSITY AT SSU* BURNER SSF	
40	ASH		44	TOTAL HYDROGEN % wt	11.76
	TOTAL		41	Btu per lb	16632
41	Btu per lb AS FIRED	16632			
42	ASH SOFT TEMP.* ASTM METHOD			GAS	% VOL
	COAL OR OIL AS FIRED ULTIMATE ANALYSIS		54	CO	
43	CARBON	77.54	55	CH_4 METHANE	
44	HYDROGEN	11.76	56	C_2H_2 ACETYLENE	
45	OXYGEN		57	C_2H_4 ETHYLENE	
46	NITROGEN		58	C_2H_6 ETHANE	
47	SULPHUR	.05	59	H_2S	
40	ASH	5	60	CO_2	
37	MOISTURE	3.5	61	H_2 HYDROGEN	
	TOTAL			TOTAL	
	COAL PULVERIZATION			TOTAL HYDROGEN % wt	
48	GRINDABILITY INDEX*		62	DENSITY 68 F ATM. PRESS.	
49	FINENESS % THRU 50 M*		63	Btu PER CU FT	
50	FINENESS % THRU 200 M*		41	Btu PER LB	
64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29			

HEAT LOSS EFFICIENCY

		Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS	1534.15	9.224
66	HEAT LOSS DUE TO MOISTURE IN FUEL	43.47	.261
67	HEAT LOSS DUE TO H_2O FROM COMB. OF H_2	1314.53	7.90
68	HEAT LOSS DUE TO COMBUST. IN REFUSE		
69	HEAT LOSS DUE TO RADIATION		1.6
70	UNMEASURED LOSSES		1.0
71	TOTAL		19.985
72	EFFICIENCY = (100 – Item 71)		80.015

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

Printed in U.S.A. (10/74)

This Test Form (C-36) may be obtained from ASME, 345 E. 47 St., New York, N.Y. 1

PTC 4.1-b (1964)

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

CULATION SHEET

Revised September, 1965

OWNER OF PLANT | TEST NO. | BOILER NO. | DATE

0 HEAT OUTPUT IN BOILER BLOW-DOWN WATER = LB OF WATER BLOW-DOWN PER HR × [(ITEM 15 − ITEM 17) / 1000] = ... LB/hr

If impractical to weigh refuse, this item can be estimated as follows

4 DRY REFUSE PER LB OF AS FIRED FUEL = (% ASH IN AS FIRED COAL) / (100 − % COMB. IN REFUSE SAMPLE)

CARBON BURNED PER LB AS FIRED FUEL = (ITEM 43 / 100) − [(ITEM 22 × ITEM 23) / 14,500] = 77.54 / 100 − [(0 × 0) / 14,500] = .7754

NOTE: IF FLUE DUST & ASH PIT REFUSE DIFFER MATERIALLY IN COMBUSTIBLE CONTENT, THEY SHOULD BE ESTIMATED SEPARATELY. SEE SECTION 7, COMPUTATIONS.

DRY GAS PER LB AS FIRED FUEL BURNED = $\frac{11CO_2 + 8O_2 + 7(N_2 + CO)}{3(CO_2 + CO)}$ × (LB CARBON BURNED PER LB AS FIRED FUEL + $\frac{3}{8}$ S)

25 = $\frac{11 \times 13.2 + 8 \times 2.5 + 7(84.3 + 0)}{3 \times (13.2 + 0)}$ × [77.54 + (10.3 / 267)] = 14.797

EXCESS AIR† = $100 \times \frac{O_2 - \frac{CO}{2}}{.2682N_2 - (O_2 - \frac{CO}{2})}$ = $100 \times \frac{2.5 - \frac{0}{2}}{.2682(84.3) - (2.5 - \frac{0}{2})}$ = 12.43

	HEAT LOSS EFFICIENCY	Btu/lb AS FIRED FUEL	LOSS / HHV × 100 =	LOSS %
6	HEAT LOSS DUE TO DRY GAS = LB DRY GAS PER LB AS FIRED FUEL × C_p × (t_{vg} − t_{air}) = 14.797 × 0.24 × (520 − 88) =	1534.15	65/41 × 100 =	9.224
6A	HEAT LOSS DUE TO MOISTURE IN FUEL = LB H_2O PER LB AS FIRED FUEL × [(ENTHALPY OF VAPOR AT 1 PSIA & T GAS LEAVG) − (ENTHALPY OF LIQUID AT T AIR)] = ITEM 37 / 100 × [(ENTHALPY OF VAPOR AT 1 PSIA & T ITEM 13) − (ENTHALPY OF LIQUID AT T ITEM 11)] = 3.5/100 × [1248 − 56] =	43.47	66/41 × 100 =	.261
6	HEAT LOSS DUE TO H_2O FROM COMB. OF H_2 = 9H_2 × [(ENTHALPY OF VAPOR AT 1 PSIA & T GAS LVG) − (ENTHALPY OF LIQUID AT T AIR)] = 9 × ITEM 44 / 100 × [(ENTHALPY OF VAPOR AT 1 PSIA & T ITEM 13) − (ENTHALPY OF LIQUID AT T ITEM 11)] = 11.76/100 × [1248 − 56] =	1314.53	67/41 × 100 =	7.90
6B	HEAT LOSS DUE TO COMBUSTIBLE IN REFUSE = ITEM 22 × ITEM 23 =	Not measured.	68/41 × 100 =	
69	HEAT LOSS DUE TO RADIATION* = TOTAL BTU RADIATION LOSS PER HR / LB AS FIRED FUEL − ITEM 28	From ABMA chart	69/41 × 100 =	1.6
70	UNMEASURED LOSSES **		70/41 × 100 =	1.0
71	TOTAL			14.985
	EFFICIENCY = (100 − ITEM 71)			80.015

† rigorous determination of excess air see Appendix 9.2 – PTC 4.1-1964

* losses are not measured, use ABMA Standard Radiation Loss Chart, Fig. 8, PTC 4.1-1964

** Unmeasured losses listed in PTC 4.1 but not tabulated above may by provided for by assigning a mutually agreed upon value for Item 70.

This Test Form (C-37) may be obtained from ASME, 345 E. 47 St., New York, N.Y. 10017

UMMARY SHEET

ASME TEST FORM FOR ABBREVIATED EFFICIENCY TEST

PTC 4.1-a (1964)

55% load on boiler — TEST NO 1 — BOILER NO. — DATE 6.6.1975

OWNER OF PLANT Commonwealth — LOCATION Plant 2 Black Creek

TEST CONDUCTED BY Hall — OBJECTIVE OF TEST — DURATION

BOILER MAKE & TYPE Volcano WS 35 — RATED CAPACITY 35,000 lb/hr

STOKER TYPE & SIZE

PULVERIZER, TYPE & SIZE — BURNER, TYPE & SIZE Todd

FUEL USED CC — MINE Irving — COUNTY — STATE — SIZE AS FIRED

PRESSURES & TEMPERATURES

1	STEAM PRESSURE IN BOILER DRUM	psia	125
2	STEAM PRESSURE AT S. H. OUTLET	psia	
3	STEAM PRESSURE AT R. H. INLET	psia	
4	STEAM PRESSURE AT R. H. OUTLET	psia	
5	STEAM TEMPERATURE AT S. H. OUTLET	F	Sat. Temp
6	STEAM TEMPERATURE AT R H INLET	F	
7	STEAM TEMPERATURE AT R. H. OUTLET	F	
8	WATER TEMP. ENTERING (ECON.) (BOILER)	F	220
9	STEAM QUALITY % MOISTURE OR P. P. M.		
10	AIR TEMP. AROUND BOILER (AMBIENT)	F	73
11	TEMP AIR FOR COMBUSTION (This is Reference Temperature) †	F	73
12	TEMPERATURE OF FUEL	F	140
13	GAS TEMP. LEAVING (Boiler) (Econ.) (Air Htr.)	F	502
14	GAS TEMP. ENTERING AH (If conditions to be corrected to guarantee)	F	—

UNIT QUANTITIES

15	ENTHALPY OF SAT. LIQUID (TOTAL HEAT)	Btu/lb	345
16	ENTHALPY OF (SATURATED) (SUPERHEATED) STM.	Btu/lb	1191
17	ENTHALPY OF SAT. FEED TO (BOILER) (ECON.)	Btu/lb	188
18	ENTHALPY OF REHEATED STEAM R. H. INLET	Btu/lb	-
19	ENTHALPY OF REHEATED STEAM R. H. OUTLET	Btu/lb	—
20	HEAT ABS. LB OF STEAM (ITEM 16 – ITEM 17)	Btu/lb	1003
21	HEAT ABS. LB R.H. STEAM (ITEM 19 – ITEM 18)	Btu/lb	—
22	DRY REFUSE (ASH PIT + FLY ASH) PER LB AS FIRED FUEL	lb/lb	
23	Btu PER LB IN REFUSE (WEIGHTED AVERAGE)	Btu/lb	
24	CARBON BURNED PER LB AS FIRED FUEL	lb/lb	.86
25	DRY GAS PER LB AS FIRED FUEL BURNED	lb/lb	15.71

HOURLY QUANTITIES

26	ACTUAL WATER EVAPORATED	lb/hr	19200
27	REHEAT STEAM FLOW	lb/hr	
28	RATE OF FUEL FIRING (AS FIRED wt)	lb/hr	
29	TOTAL HEAT INPUT (Item 28 x Item 41) / 1000	kB/hr	
30	HEAT OUTPUT IN BLOW-DOWN WATER	kB/hr	
31	TOTAL HEAT OUTPUT (Item 26 x Item 20) + (Item 27 x Item 21) + Item 30 / 1000	kB/hr	

FLUE GAS ANAL. (BOILER) (ECON) (AIR HTR) OUTLET

32	CO_2	% VOL	13.8
33	O_2	% VOL	.75
34	CO	% VOL	0
35	N_2 (BY DIFFERENCE)	% VOL	85.45
36	EXCESS AIR	%	1.38

FUEL DATA

	COAL AS FIRED PROX. ANALYSIS	% wt	
37	MOISTURE		
38	VOL MATTER		
39	FIXED CARBON		
40	ASH		
	TOTAL		
41	Btu per lb AS FIRED	1830	
42	ASH SOFT TEMP.* ASTM METHOD		
	COAL OR OIL AS FIRED ULTIMATE ANALYSIS		
43	CARBON	86	
44	HYDROGEN	11	
45	OXYGEN		
46	NITROGEN		
47	SULPHUR	3	
40	ASH		
37	MOISTURE		
	TOTAL		
	COAL PULVERIZATION		
48	GRINDABILITY INDEX*		
49	FINENESS % THRU 50 M*		
50	FINENESS % THRU 200 M*		
64	INPUT-OUTPUT EFFICIENCY OF UNIT %	ITEM 31 × 100 / ITEM 29	

	OIL		
51	FLASH POINT F*		
52	Sp. Gravity Deg. API*		
53	VISCOSITY AT SSU* BURNER SSF		
44	TOTAL HYDROGEN % wt		
41	Btu per lb		
	GAS	% VOL	
54	CO		
55	CH_4 METHANE		
56	C_2H_2 ACETYLENE		
57	C_2H_4 ETHYLENE		
58	C_2H_6 ETHANE		
59	H_2S		
60	CO_2		
61	H_2 HYDROGEN		
	TOTAL		
	TOTAL HYDROGEN % wt		
62	DENSITY 68 F ATM. PRESS.		
63	Btu PER CU FT		
41	Btu PER LB		

	HEAT LOSS EFFICIENCY	Btu/lb A. F. FUEL	% of A. F. FUEL
65	HEAT LOSS DUE TO DRY GAS		5.11
66	HEAT LOSS DUE TO MOISTURE IN FUEL		.6
67	HEAT LOSS DUE TO H_2O FROM COMB OF H_2		6.[illegible]
68	HEAT LOSS DUE TO COMBUST. IN REFUSE		.0
69	HEAT LOSS DUE TO RADIATION		1.6
70	UNMEASURED LOSSES		1.0
71	TOTAL		15.21
72	EFFICIENCY = (100 – Item 71)		84.79

* Not Required for Efficiency Testing

† For Point of Measurement See Par. 7.2.8.1-PTC 4.1-1964

This Test Form (C-36) may be obtained from ASME, 345 E. 47 St., New York, N.Y. 10

PTC 4.1-b (1964)

ASME TEST FORM
FOR ABBREVIATED EFFICIENCY TEST

ALCULATION SHEET *Revised September, 1965*

OWNER OF PLANT | TEST NO. | BOILER NO. | DATE

30 HEAT OUTPUT IN BOILER BLOW-DOWN WATER = LB OF WATER BLOW-DOWN PER HR × [(ITEM 15 − ITEM 17) / 1000] = ... kB/hr

24 *If impractical to weigh refuse, this item can be estimated as follows*

DRY REFUSE PER LB OF AS FIRED FUEL = % ASH IN AS FIRED COAL / (100 − % COMB. IN REFUSE SAMPLE)

CARBON BURNED PER LB AS FIRED FUEL = ITEM 43 / 100 − [ITEM 22 × ITEM 23 / 14,500] = ...

NOTE: IF FLUE DUST & ASH PIT REFUSE DIFFER MATERIALLY IN COMBUSTIBLE CONTENT, THEY SHOULD BE ESTIMATED SEPARATELY. SEE SECTION 7, COMPUTATIONS.

25 DRY GAS PER LB AS FIRED FUEL BURNED = [11(CO₂ + BO₂ + 7(N₂ + CO)) / 3(CO₂ + CO)] × (LB CARBON BURNED PER LB AS FIRED FUEL + 3/8 S)

= [11 × ITEM 32 + 8 × ITEM 33 + 7 × (ITEM 35 − ITEM 34)] / [3 × (ITEM 32 + ITEM 34)] × [ITEM 24 + ITEM 47 / 267] = ...

36 EXCESS AIR[1] = 100 × (O₂ − CO/2) / (.2682N₂ − (O₂ − CO/2)) = 100 × (ITEM 33 − ITEM 34/2) / (.2682 (ITEM 35) − (ITEM 33 − ITEM 34/2)) = ...

	HEAT LOSS EFFICIENCY	Btu/lb AS FIRED FUEL	LOSS/HHV × 100 =	LOSS %
65	HEAT LOSS DUE TO DRY GAS = LB DRY GAS PER LB AS FIRED FUEL × C_p × (t_{avg} − t_{air}) = ITEM 25 × 0.24 × (ITEM 13) − (ITEM 11) = ...	.....	65/41 × 100 = ...	.....
66	HEAT LOSS DUE TO MOISTURE IN FUEL = LB H_2O PER LB AS FIRED FUEL × [(ENTHALPY OF VAPOR AT 1 PSIA & T GAS LVG) − (ENTHALPY OF LIQUID AT T AIR)] = ITEM 37 / 100 × [(ENTHALPY OF VAPOR AT 1 PSIA & T ITEM 13) − (ENTHALPY OF LIQUID AT T ITEM 11)] = ...	.....	66/41 × 100 = ...	.....
67	HEAT LOSS DUE TO H_2O FROM COMB. OF H_2 = 9H_2 × [(ENTHALPY OF VAPOR AT 1 PSIA & T GAS LVG) − (ENTHALPY OF LIQUID AT T AIR)] = 9 × ITEM 44 / 100 × [(ENTHALPY OF VAPOR AT 1 PSIA & T ITEM 13) − (ENTHALPY OF LIQUID AT T ITEM 11)] = ...	.....	67/41 × 100 = ...	.....
68	HEAT LOSS DUE TO COMBUSTIBLE IN REFUSE = ITEM 22 × ITEM 23 = ...	.....	68/41 × 100 = ...	.....
69	HEAT LOSS DUE TO RADIATION* = TOTAL BTU RADIATION LOSS PER HR / LB AS FIRED FUEL = ITEM 28 /	.....	69/41 × 100 = ...	.....
70	UNMEASURED LOSSES **	.....	70/41 × 100 = ...	.....
71	TOTAL	.....	.....	.....
72	EFFICIENCY = (100 − ITEM 71)	.....	.....	.....

[1] For rigorous determination of excess air see Appendix 9.2 – PTC 4.1-1964

* If losses are not measured, use ABMA Standard Radiation Loss Chart, Fig. 8, PTC 4.1-1964

** Unmeasured losses listed in PTC 4.1 but not tabulated above may by provided for by assigning a mutually agreed upon value for Item 70.

This Test Form (C-37) may be obtained from ASME, 345 E. 47 St., New York, N.Y. 10017

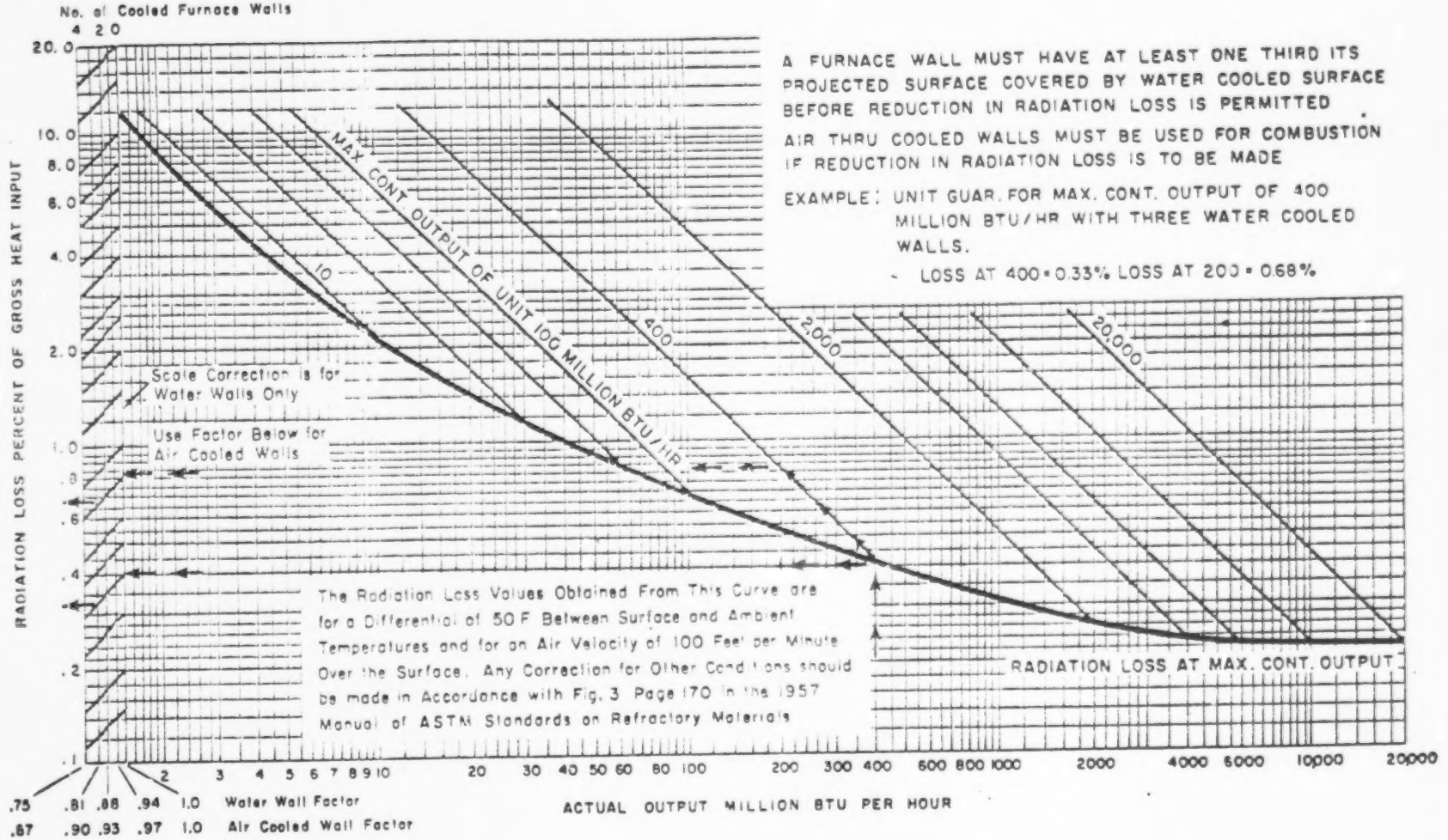

No. of Cooled Furnace Walls
4 2 0
RADIATION LOSS PERCENT OF GROSS HEAT INPUT
20.0
10.0
8.0
6.0
4.0
2.0
1.0
.8
.6
.4
.2
.1
A FURNACE WALL MUST HAVE AT LEAST ONE THIRD ITS PROJECTED SURFACE COVERED BY WATER COOLED SURFACE BEFORE REDUCTION IN RADIATION LOSS IS PERMITTED
AIR THRU COOLED WALLS MUST BE USED FOR COMBUSTION IF REDUCTION IN RADIATION LOSS IS TO BE MADE
EXAMPLE: UNIT GUAR. FOR MAX. CONT. OUTPUT OF 400 MILLION BTU/HR WITH THREE WATER COOLED WALLS.
- LOSS AT 400 = 0.33% LOSS AT 200 = 0.68%
MAX. CONT. OUTPUT OF UNIT 100 MILLION BTU/HR.
10
400
2,000
20,000
Scale Correction is for Water Walls Only
Use Factor Below for Air Cooled Walls
The Radiation Loss Values Obtained From This Curve are for a Differential of 50 F Between Surface and Ambient Temperatures and for an Air Velocity of 100 Feet per Minute Over the Surface. Any Correction for Other Conditions should be made in Accordance with Fig. 3 Page 170 in the 1957 Manual of ASTM Standards on Refractory Materials
RADIATION LOSS AT MAX. CONT. OUTPUT
1 2 3 4 5 6 7 8 9 10 20 30 40 50 60 80 100 200 300 400 600 800 1000 2000 4000 6000 10000 20000
ACTUAL OUTPUT MILLION BTU PER HOUR
.75 .81 .88 .94 1.0 Water Wall Factor
.87 .90 .93 .97 1.0 Air Cooled Wall Factor

FIGURE B. RADIATION AND CONVECTION HEAT LOSS CHART, ASSUMING EMISSIVITY = 0·95.
PUBLISHED BY COURTESY OF THE AMERICAN BOILER MANUFACTURERS ASSOCIATION.

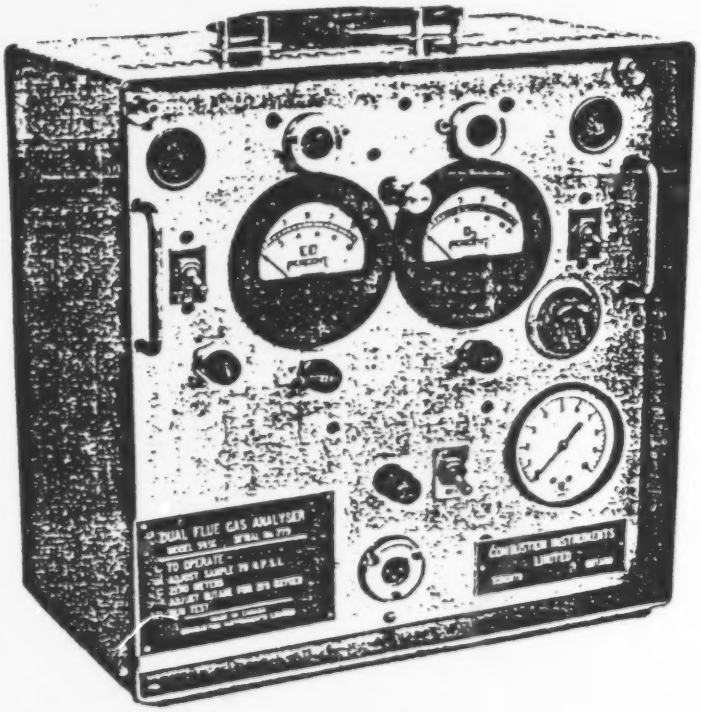
APPENDIX D

SPECIFICATIONS OF INSTRUMENTS USED

BULLETIN NO. 59

PORTABLE DUAL FLUE GAS ANALYSER

FOR CONTINUOUS MEASUREMENTS OF OXYGEN AND COMBUSTIBLES



MODEL 59

Ranges	0 - 5 and 0 - 21% Oxygen 0 - 1 and 0 - 10% Combustibles
Weight	18 lbs.
Size	6" x 12" x 12"
Power	115 Volt - 60 Hz

SPECIAL FEATURES

1. Sample condensation trap
2. Double pass sample scrubber
3. Continuous sample indication
4. Visual operating filaments
5. On the job instructions

Model 59 is designed primarily for boiler work, but functions equally well in setting up or checking oxidizing or reducing atmospheres in the bright annealing of metals, endothermic and exothermic generators, open hearth and glass tank operations, and numerous other applications where fuel costs, scrap costs, refractory brick work failure or customer dissatisfaction erodes profits.

Our representative would be pleased to arrange a demonstration at your plant on your problems.

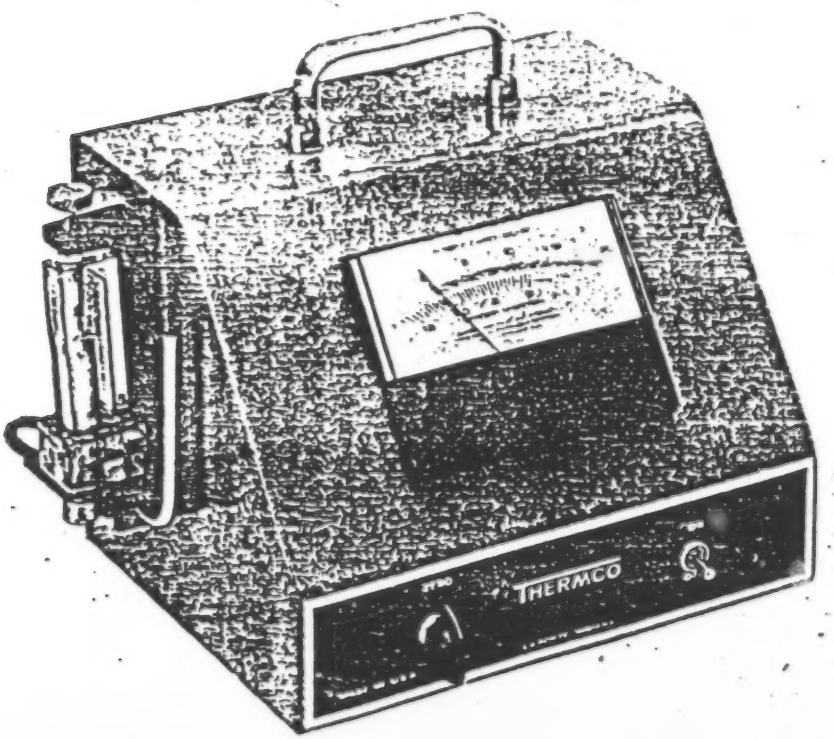
COMBUSTION INSTRUMENTS LIMITED

Thermco
INSTRUMENT CORPORATION

P-11 Efficiency Model, The Work Horse, Range: 0-20% CO_2

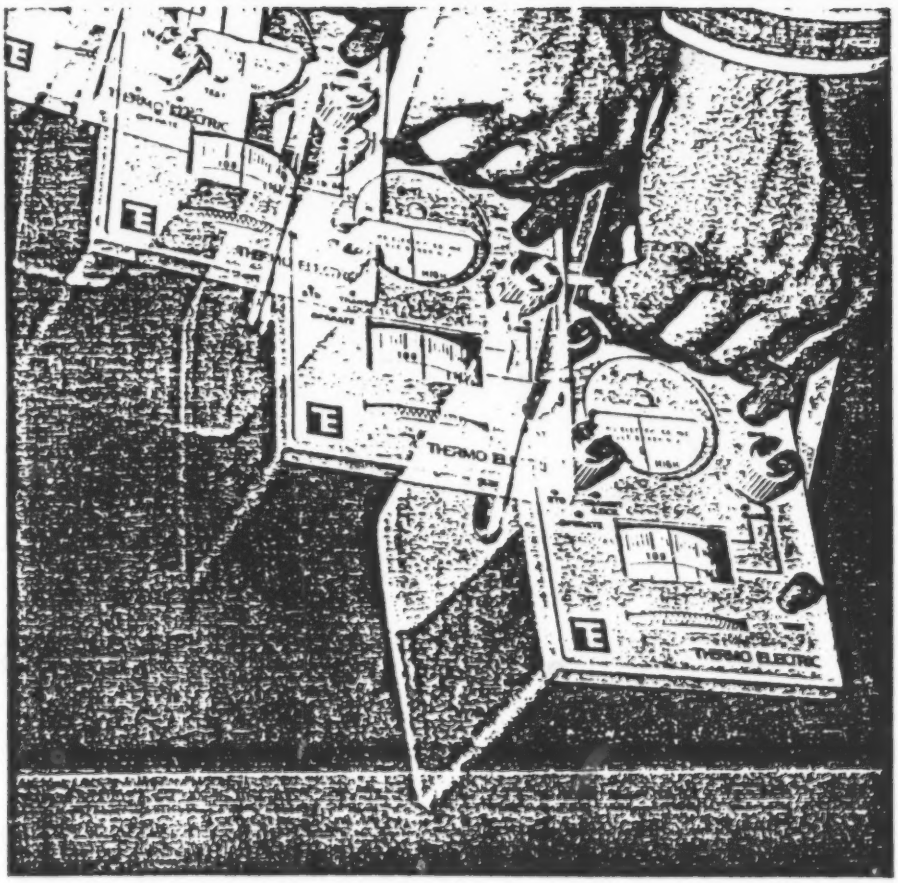
SPECIFICATIONS

Method of Analysis	Thermal Conductivity
Accuracy 1/2% CO_2	Model P-11, P-12, P-18, P-18T & P-20
Speed of Response	90% - 30 seconds
Sample Flow	1 cfh
Temperature Range	40° - 110°F.
Sample Temperature	32° - 3200°F. with proper Sampling Tube
Indicator	4-1/2" wide View Meter
Power Required (Standard Models)	115V., 60 Hz., 5 Watts
Size	8 x 10 x 8
Weight	15 lbs.



Portable MINIMITE®

temperature-millivolt potentiometer



A rugged, dual scale potentiometer for industrial, field and laboratory use.

±¼% accuracy
Checks thermocouple and millivolt inputs
Calibrates potentiometer instruments
2 foot calibrated scale
Self-contained, battery operated
Automatic reference junction compensation

MultiMite® (page 8)
Compact multipurpose instrument
Calibrates D'Arsonval and potentiometer pyrometers
Models for checking up to 6 or 12 thermocouples

THERMO ELECTRIC
Saddle Brook, New Jersey 07662
Brampton, Ontario L6W 3J2
Leiden, Box 515, The Netherlands
©1970 Thermo Electric Co. Inc.
Printed USA, Section 2 mm, Edition 4

Specifications MODEL 200 DEWPOINT METER

MAXIMUM OPERATING TEMPERATURE:

Probe: Detector end: 400°C (750°F)
Terminal end: 60°C (140°F)
Control unit: 40°C (104°F)

DETECTOR:

Borosilicate glass thimble with a platinum ring electrode and platinum vs platinum – 13% rhodium thermocouple fused into the polished end face.

PROBE:

Stainless steel body. Operating lengths: 1.2m (4ft), 2.1m (7ft), 3m (10ft). max. dia. 38mm (1.5 inch). Air cooled. Includes two 3m (10 ft) air hoses with quick connect, self sealing connectors and one 3/8 NPT male end. Supplied with detector and wiring in place. Connector: Cannon, 6-pin.
Iron-Constantan stainless steel sheathed auxiliary thermocouple (replaceable) mounted to probe.
Probe Carrying Case (supplied): moulded ABS plastic 152cm x 30cm x 10cm (60" x 12" x 4") foam lined with handles and latches.
Weight of carrying case with probe and air lines: 4.5 kg (10 lbs).

CONTROL UNIT:

Housed in reinforced plastic carrying case with hinged cover, latch and handle: 20cm x 26.6cm x 21.6cm (8" x 10-5/8" x 8-5/8")
weight: 5.44 kg (12 lbs.)

Temperature Indicator: Three scales, mirrored scale, sealed and shock resistant.
Detector scales: 0 to 460°C, 0 to 180°C (0 to 860°F, 0 to 350°F).
Flue gas scale: – 20 to 540°C (0 to 1000°F).

Current/RBU Indicator: Four scales, mirrored scale, sealed and shock resistant.
Current scales: 0 to 100, 500, 5000 microamps.
RBU scale: 0 to 1000 microamp/minute.

Switches: Toggle, sealed, silver contacts. On-Off; Flue Gas – Detector select; Detector range select; Current-RBU select; Current range select.

Electronics: All solid state, mounted on plug-in circuit cards. Conductivity circuit power supply fixed and regulated at 10 volts, 100Hz.

Other: Air flow control valve. Power cord, 3m (10 ft), stores in case cover. Probe interconnect cable, 3m (10 ft) stores in case cover.

Accuracy: Over full ambient range of control unit, 0 to 40°C (32 to 104°F). Thermocouple accuracy is ±2deg C (± 4deg F). Meter accuracy: 1%.

SERVICES REQUIRED:

Electrical: 115 VAC 50-440 Hz - North America
115/230 VAC 50-440 Hz - EEC

Air: Clean; dry compressed air 0.14 m^3/min. at 2.8kg/cm^2 (5cfm at 40 psig) typical; maximum: 7.0kg/cm^2 (100 psig).

Conforms to BS 1756: Part 4: 1965 on determination of acid dewpoint temperature.